ALLUVIAL VALLEY FLOOR IDENTIFICATION AND STUDY GUIDELINES

U.S. DEPARTMENT OF THE INTERIOR

Office of Surface Mining Reclamation and Enforcement

August 1983

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INTRODUCTION

This handbook reviews regulatory and technical aspects of alluvial valley floors, important issues to coal mining in the semiarid and arid parts of the Western United States. The information contained in this handbook should be helpful to the coal mine operator, interested citizen, regulatory agency, and land mangement agency in identifying, studying, and predicting impacts to alluvial valley floors. In developing this handbook, the Office of Surface Mining used the experience gained by this office and the States in dealing with alluvial valley floors since the passage of the Surface Mining Control and Reclamation Act of 1977. The handbook uses this experience to guide the reader toward certain study approaches. However, it is emphasized that this handbook is solely an advisory document and the only fixed requirements relating to alluvial valley floors are contained in the statute itself or in the adopted regulations.

This handbook is designed to review (1) the regulatory process, (2) the identification of alluvial valley floors, (3) studies of alluvial valleys necessary for inclusion in permit applications, and

(4) the technical literature related to selected pertinent topics. The study of alluvial valley floors is a particularly difficult issue on which to provide clear guidance. The natural environment of the West is highly diverse, and the characteristics of alluvial valley floors differ widely from North Dakota to New Mexico. Studies necessary to allow a regulatory agency to make its required findings range from simple to complex, depending on the characteristics of the valley and the particular mining proposal. This handbook attempts to outline the types of questions which need to be considered and the study methods available. Any particular study plan, however, must be developed for a site-specific area.

No handbook can eliminate the need for close communication between a permit applicant and the regulatory authority. Specific study areas and plans should be reviewed prior to full-scale commitment by the applicant to a study program. Good communication can avoid many problems and encourage efficient decisionmaking.

Understanding of the roles of both the applicant for a mining permit and the regulatory authority is important to ensure efficient mine permitting. The applicant has the responsibility to develop the data to support any determination, be it a designation of an alluvial valley floor or the definition of essential hydrologic functions. These data must be accurate, analyzed, and presented in such a manner as to facilitate the decisionmaking of the regulatory agency. The

role of the regulatory authority is to review data presented by the applicant or obtained from other sources and to make defensible written determinations within a reasonable timeframe.

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CHAPTER I

ALLUVIAL VALLEY FLOOR REGULATORY PROCESS

Under provisions of the Surface Mining Control and Reclamation Act of 1977 (SMCRA), (1) certain types of stream valleys in the Western United States are prohibited from disturbance by coal mining activities, whereas (2) some other types of stream valleys in the West may be mined but must meet higher standards for reclamation than those required for other types of mined areas. Both of these types of stream valleys are referred to as alluvial valley floors. The regulatory process for the alluvial valley floors issue is more complex than for most other reclamation issues because of the sequential nature of the studies and decisions which must be made by the applicant and the regulatory authority.

The provisions of the SMCRA include specific prohibition from mining certain alluvial valley floors, stringent reclamation standards for those alluvial valley floors not prohibited from mining, and requirements that mining operations not materially damage the hydrologic functions of any alluival valley floors that would otherwise be prohibited from mining.

Provisions of the SMCRA which apply to alluvial valley floors are found in three sections. Section 701 contains the definition of alluvial valley floors. Section 510(b)(5) requires that an applicant

for a mine permit affirmatively demonstrate that the proposed operation will not interrupt, discontinue, or preclude farming on alluvial valley floors (with two exceptions) and that the proposed operation will not materially damage the water supply of those alluvial valley floors not excepted. Section 515(b)(10)(F) requires preservation of the hydrologic functions of all alluvial valley floors outside the mine area and the reclamation of all alluvial valley floors disturbed by mining.

The prohibitions to mining an alluvial valley floor are outlined in Section 510(b)(5)(A) of the Act. This section generally states that no coal mining operation may "interrupt, discontinue, or preclude farming" on alluvial valley floors. This means that a mining operation is banned from disturbing any portion of an alluvial valley floor, except for those alluvial valley floors specifically excluded from this prohibition. The term "preclude" was included in the statute to ensure that a mining company does not take land out of production in order to avoid compliance with this section.

There are two types of alluvial valley floor areas which are provided exemption to the prohibition of mining. The first exemption is given to "undeveloped rangelands not significant to farming" and the second to "lands of such small acreage that their mining would have negligible impact on the farm's production." In addition, lands identified in approved reclamation plans from which coal was produced

in commercial quantities or for which permit approval was obtained in the year preceding the passage of the SMCRA are exempted, or grandfathered, from the alluvial valley floor provisions.

Protection is also mandated in Section 510(b)(5)(B) to the hydrologic systems associated with the alluvial valley floors which are banned from mining. A mining operation cannot materially damage the quantity or quality of water in surface- or ground-water systems which supply these alluvial valley floors. Therefore, it is possible that additional areas not designated as significant alluvial valley floors might be banned from mining if mining the area would cause adverse impact to a designated alluvial valley floor and adequate mitigation measures could not be taken in the mine plan to eliminate the adverse impact.

Section 515(b)(10)(F) requires that the essential hydrologic functions of all alluvial valley floors be preserved throughout the mining and reclamation process. This section mandates that all alluvial valley floors be protected during mining and reclamation. Some may be mined and reclaimed, whereas others must be protected during mining.

Section 515(b)(10)(F) also establishes the reclamation standards for those alluvial valley floors not excluded from mining under the provisions of Section 510(b)(5). Under the reclamation standards, a

coal mine must minimize the disturbances to the prevailing hydrologic balance by restoring the essential hydrologic functions of mined valleys.

Regulations implementing SMCRA were adopted March 13, 1979, as 30 CFR, Parts 700 and 800 (U.S. Department of Interior, 1979). Provisions applying to alluvial valley floors are included in:

30 CFR 701.5	Definitions
30 CFR 785.19	Requirements for Permits for Special Categories of Mining: Surface coal mining and reclamation operations on areas or adjacent to areas including alluvial valley floors in the arid or semiarid areas west of the 100th meridian.
30 CFR 822	Special Permanent Program Performance Standards: Operations in alluvial valley floors

Following adoption of the final Federal regulations, Peabody Coal and several States sued the Federal Government on numerous aspects of the regulations. The decision by the United States District Court for the District of Columbia, Civil Action No. 79-1144 (1980), known as the Flannery decision, shed light on several aspects of the alluvial valley floor regulatory program. The court sustained the OSM interpretation that alluvial valley floors may be found along perennial, intermittent, or ephemeral streams. The court noted:

> An alluvial valley floor must satisfy geologic criteria (unconsolidated stream-laid deposits meeting the regulation's dimensions) <u>and</u> hydrologic criteria (water sufficient to sustain agriculture). Hence, those ephemeral or dry streams incapable of

> supporting agriculture by natural or artificial means fail to qualify as an alluvial valley floor.
>
> The Senatorial exchange (between Senators Bartlett and Metcalf) * * * demonstrates that dry water streams without surface or subirrigation capability are excluded from the definition of an alluvial valley floor, whereas dry water streams with irrigation capability are subject to the Act's protections. The key is water availability. Congress' concern was the preservation of agriculture. This concern is protected whether the alluvial valley floor contains natural subsurface irrigation or is capable of irrigation by surface means.
>
> (p. 47-48)

Thus, the court emphasized the basis of an alluvial valley floor as containing both geomorphic and water availability attributes and which, together, have agricultural importance.

The regulatory requirements to collect detailed sets of geologic, hydrologic, soils, vegetation, and agricultural data were also upheld by the courts:

> The informational requirements of 30 CFR 785.19 are consonant with the Act. * * *. The Act thus commands an operator, who seeks to mine coal in or around an alluvial valley floor, to provide additional information in the permit application specific to the values underlying alluvial valley floor preservation. The regulations at issue merely implement these informational requirements.
>
> As to the agricultural information of Section 510(b)(5), if an alluvial valley floor fails to encompass agricultural activities, then the permit application need only present rudimentary evidence of lack of farming. * * *. However, hydrologic information must still be provided. If the permit area encompasses an alluvial valley floor, the hydrologic protections of sections 510(b)(3) and 515(b)(10)(F) apply regardless of whether farming occurs.
>
> (p. 49-50)

The court mandated minor changes, such as remanding the requirement

that a full year's hydrologic data be collected but basically upheld the notion that alluvial valley floors required detailed study.

The regulatory procedure presently followed by OSM in reviewing proposed operations on or adjacent to alluvial valley floors is a multistep process. Figure 1 is a flow chart depicting the successive investigations and determinations which must be made before permit approval can be given. In considering alluvial valley floors, the following major decisions must be made by the applicant:

1. Are there alluvial valley floors in or near the proposed permit area?

2. Are any of those alluvial valley floors subject to prohibition from mining?

3. What will be the effect of proposed mining on those nearby alluvial valley floors?

4. Can those alluvial valley floors proposed for mining be successfully reclaimed?

In order to answer each of these questions, specific data and analyses are needed. Since the answers to some questions dictate responses to other questions, it is advisable to complete the identification phase of alluvial valley floor studies prior to submittal of a formal mining and reclamation plan. Satisfactory answers to all questions must be made prior to permit approval.

Experience has shown that the identification of alluvial valley floors is best accomplished in two phases:

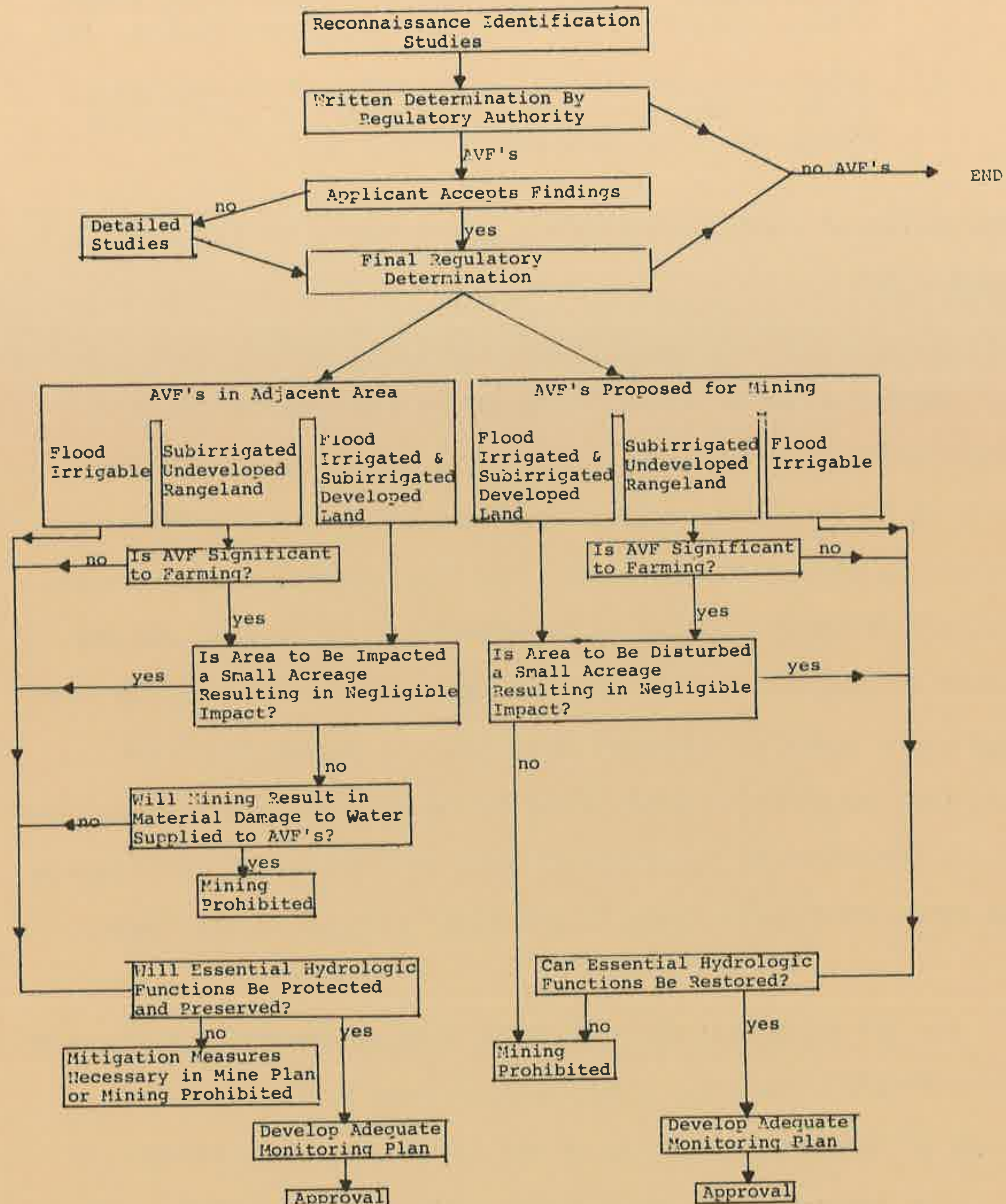

Fig. 1 Flowchart of alluvial valley floor regulatory process

1. A reconnaissance phase allows the applicant or land management agency to identify areas clearly not alluvial valley floors, as well as probable alluvial valley floors, without conducting costly and time-consuming studies; and

2. Detailed studies can then be conducted if the applicant wishes to demonstrate that any probable alluvial valley floors should not have that status.

The details of identifying alluvial valley floors are discussed in chapter II.

Whether alluvial valley floors can be mined depends on their significance to agriculture. Statutory language exempts certain portions of an alluvial valley floor from the mining prohibition and hydrologic protection provisions. The first exemption differentiates undeveloped rangeland which is not significant to farming, and the second differentiates small acreages which, if disturbed, would cause negligible impact to a farming operation. If neither condition is met, then the alluvial valley floor is significant. The proposed mine cannot disturb these "significant" areas and cannot materially damage the water which supply these "significant" alluvial valley floors.

For all designated alluvial valley floors, whether significant or insignificant to farming, a determination must be made that the essential hydrologic functions of the valley will be protected. If mining or disturbance of the alluvial valley floor is allowed, the adequacy of the reclamation plan to restore the essential hydrologic functions must be demonstrated. Finally, for all alluvial valley

floors, a monitoring program must be designed which will document that the alluvial valley floor protections afforded by the Act are being complied with during the approved mining and reclamation operation.

Chapter III discusses further the issues of significance, essential hydrologic functions, material damage, reclamation, and environmental monitoring.

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CHAPTER II

IDENTIFYING THE OCCURRENCE OF ALLUVIAL VALLEY FLOORS

In a general sense, alluvial valley floors are areas in the Western United States which (1) are located in those topograhic valleys having an associated stream channel, (2) are underlain by unconsolidated deposits whose surface usually has the landform appearance of flood plains or terraces, and (3) have an agricultural importance derived from the availability of surface or ground water. The ultimate goal of alluvial valley floor identificaton investigations is to identify stream valleys which have agricultural importance and where that importance is derived from the water available in those valleys. Stream valleys which do not have any agricultural importance or whose importance is not related to the greater water availability of the valleys are not alluvial valley floors. Because the environmental characteristics, agricultural uses, and irrigation practices of stream valleys vary in the different regions of the West, the specific rationale used for identifying or determining the role and character of alluvial valley floors may vary from region to region. A regional understanding of irrigation and agricultural practices is a prerequisite to making assessments of alluvial valley floor status.

Experience has shown that a phased approach to the identificaton of alluvial valley floors is often desirable (table 1). In such a

phased approach, readily available data are used to make initial determinations of land status as alluvial valley floors, and increasing amounts of detailed data are collected to resolve any uncertainties. The needs of various agencies and industry also differ in the certainty of decisions needed. Land management agencies usually wish to make initial identifications on the basis of readily or easily obtainable data. Surface mine permit applications, on the other hand, often require more specific characterization of the environment.

A three-step process is suggested in this handbook for identifying alluvial valley floors. First, the applicant, or land management agency, uses readily obtainable data, including regional data collecting, to make initial identifications. Second, for permit applications the regulatory authority can make an initial determination of the existence of alluvial valley floors on the basis of the data submitted by the applicant. Third, the applicant has the opportunity to conduct more detailed studies if there is disagreement with the regulatory authority's findings. This step is optional. If no contest of the initial findings is made, the identification based on readily obtainable data can be sufficient for identification purposes.

At the identification stage discussed in this chapter, precise boundaries may not be able to be assigned to all parts of an alluvial

TABLE 1

SUGGESTED PHASING OF ALLUVIAL VALLEY FLOOR IDENTIFICATION STUDIES

Study level	Potential users	Data requirements
Initial studies (including initial regulatory decisions)	Land management agencies -- land use planning	Available data
	Land management agencies --leasing studies	Regional studies
	Mine operators--preliminary planning	Reconnaissance and historical site data
Further studies	Mine operators--permit applications	Site data to resolve uncertainties of initial studies

valley floor nor may they be necessary. Precise boundaries must, however, be established before permit approval can be granted. Studies suggested later in this guideline may provide the needed definition for the boundaries. The primary goal of the identification process should be to establish whether alluvial valley floors exist.

Interaction Between Applicant and Regulatory Authority

All coal mining regulatory authorities agree that continuing interaction between the applicant and the reviewing agency is essential. No statute, regulation, or guidelines can address every issue concerning a proposed mining site. Nor can a guideline anticipate ongoing policy development within agencies which might affect study plans. Prior to developing a study program, the applicant is therefore urged to consult with the appropriate regulatory authority about the proposed project and its projected impacts. As the applicant's study progresses, continuing contact and communication with regulatory personnel can help avert problems of interpretation, scope, and detail.

What is an Alluvial Valley Floor?

Although "alluvial valley floor" has a technical meaning, particularly to a geologist, in the context of the Surface Mining Control and Reclamation Act (SMCRA), the term has a regulatory meaning. Failure to understand that "alluvial valley floor" is a regulatory term, definied in statute and clarified in legislative

history, court decisions, regulations, and ongoing administrative decisions, can result in incomplete or misdirected studies. The SMCRA defines alluvial valley floor as:

> the unconsolidated stream-laid deposits holding streams with water availability sufficient for subirrigation or flood irrigation agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits formed by unconcentrated runoff or slope wash, together with talus, or other mass-movement accumulations and windblown deposits.

The term is, therefore, an integration of concepts in geology, hydrology, and agricultural land use (fig. 2). Alluvial valley floors are not merely those valleys filled with alluvium.

"Alluvial valley floor" is a term that was first mentioned in the context of coal mining by the National Academy of Sciences (1974) in a report concerning reclamation of Western lands. The Academy noted the susceptibility to erosion of unconsolidated alluvial deposits and the relationship of gullying to declining ground-water levels and lost productivity of affected lands. The Academy suggested that "alluvial valley floors and stream channels be preserved" (p. 45). The Academy used the term as would a geologist and did not distinguish types of valleys or their relative importance to agriculture.

During congressional debates concerning coal mine reclamation in the mid-1970's, focus turned to protection of certain types of valleys--those of most importance to agricultural operations:

Fig. 2 View of Rosebud Creek near Slough Grass Coulee, southeastern Montana. Hay meadows are subirrigated.

> Of special importance in the arid and semiarid coal mining areas are alluvial valley floors which are the productive lands that form the backbone of the agricultural and cattle ranching economy of these areas. For instance, in the Powder River Basin of eastern Montana and Wyoming, agricultural and ranching operations which form the basis of the existing economic system of the region could not survive without hay production from the naturally subirrigated and flood irrigated meadows located on the alluvial valley floors. (U.S. House of Representatives, Committee on Interior and Insular Affairs, 1976).

The understanding of an alluvial valley floor is well described in this statement and has been consistently understood in the subsequent passage and implementation of the SMCRA.

The two major aspects of an alluvial valley floor--geology and water resources--are discussed more extensively in the following sections.

A. Geology. As already noted, one of the two fundamental aspects of an alluvial valley floor is its geologic character. Regulations, judicial review, and administrative decisions have expanded and clarified the statutory definition. The geologic criteria of an alluvial valley floor are understood to be:

(a) A TOPOGRAPHIC VALLEY WITH A CONTINUOUS PERENNIAL, INTERMITTENT, OR EPHEMERAL STREAM CHANNEL RUNNING THROUGH IT; AND

(b) WITHIN THAT VALLEY, THOSE SURFACE LANDFORMS THAT ARE EITHER FLOOD PLAINS OR TERRACES IF THESE LANDFORMS ARE UNDERLAIN BY UNCONSOLIDATED DEPOSITS; AND

(c) WITHIN THAT VALLEY, THOSE SIDE-SLOPE AREAS THAT CAN REASONABLY BE SHOWN TO BE UNDERLAIN BY ALLUVIUM AND WHICH ARE ADJACENT TO FLOOD PLAIN OR TERRACE LANDFORM AREAS.

Areas which are not alluvial valley floors include (1) terrace landforms not found in topographic valleys with stream channels in them, (2) lake deposits, (3) windblown deposits not meeting the criteria of (c) above, (4) residual deposits, and (5) bedrock. A description of each of these deposit types is included in appendix A.

The criteria of an alluvial valley floor place greatest emphasis on identification of alluvial landforms and secondary importance on detailed stratigraphic descriptions of deposits. Only in these valleys where the sloping land adjacent to terraces can be shown to be underlain by the same deposits that underlie the terraces is the knowledge of stratigraphy important in the identification process. Because the kind of stratigraphic data needed for the criteria of (c) is often not available during initial studies, these criteria are usually not applied until formal permit application review is completed.

<u>B. Water Resources</u>. An alluvial valley floor is not merely an area meeting geologic criteria. It is also an area with water availability sufficient for subirrigation or flood irrigation

agricultural activities. Most of the confusion and disagreement in identifying alluvial valleys is a function of different perspectives on whether water availability in a specific valley is actually sufficient for agricultural activities. Apendix B describes surface-water irrigation practices in the West, and appendix C describes subirrigation and its evaluation.

Legislative, judicial, and administrative interpretation of alluvial valley floors indicate that the water availability criteria are met if:

> (a) WATER IS AVAILABLE BY SURFACE-WATER IRRIGATION OR SUBIRRIGATION AND IS BEING OR HAS SUCCESSFULLY BEEN USED TO ENHANCE PRODUCTION OF AGRICULTURALLY USEFUL VEGETATION; OR
>
> (b) SURFACE WATER IS AVAILABLE IN SUFFICIENT QUANTITIES TO SUPPORT AGRICULTURAL ACTIVITIES.

The term "flood irrigation" means natural flood overflow or irrigation using surface waters in the methods typical for a given region. Not all styles of surface-water irrigation are appropriate for all Western coal regions. Appendix B outlines typical Western irrigation practices.

The term "subirrigation" is understood to mean the supply of water to plant roots from an underlying alluvial ground-water system such that the vegetation is more productive than in other areas and that the vegetation continues to grow during the moisture-stress portion of the growing season. Some low-lying areas have greater

vegetation productivity than adjacent uplands merely because of better soils, snow drift accumulation, or occassional flood overflow. These areas are not considered to be subirrigated, and one of the tasks of identification studies is to distinguish those valley areas whose productivity is a result of subirrigation, and not a result of water from some other source. The water availability criterion excludes areas that could be developed for subirrigation; e.g., by establishing deep rooting alfalfa to tap ground water not presently used by native vegetation.

The identification process described in the next section suggests a method of assessing water availability using regional and site-specific data.

DEFINITION OF AN ALLUVIAL VALLEY FLOOR

AN ALLUVIAL VALLEY FLOOR IS DEFINIED BY THE EXISTENCE OF FLOOD PLAINS AND TERRACES UNDERLAIN BY UNCONSOLIDATED STREAM-LAID DEPOSITS, THE AVAILABILITY OF WATER BY FLOOD IRRIGATION OR SUBIRRIGATION, AND THE USE, OR POTENTIAL USE, OF THAT WATER AND LAND FOR AGRICULTURAL PURPOSES. THE STUDIES DESCRIBED IN THIS SECTION ARE AT A RECONNAISSANCE LEVEL AND ARE USED TO IDENTIFY THE EXISTENCE OF THESE COMPONENTS OF ALLUVIAL VALLEY FLOORS. AN ALLUVIAL VALLEY FLOOR IS DETERMINED TO EXIST WHEN THE FOLLOWING CRITERIA ARE MET:

1. GEOLOGIC CRITERIA:

   a. A TOPOGRAPHIC VALLEY WITH A CONTINUOUS PERENNIAL, INTERMITTENT, OR EPHEMERAL STREAM CHANNEL RUNNING THROUGH IT; AND

   b. WITHIN THAT VALLEY, THOSE SURFACE LANDFORMS THAT ARE EITHER FLOOD PLAINS OR TERRACES IF THESE LANDFORMS ARE UNDERLAIN BY UNCONSOLIDATED DEPOSITS; AND

   c. WITHIN THAT VALLEY, THOSE SIDE-SLOPE AREAS THAT CAN REASONABLY BE SHOWN TO BE UNDERLAIN BY ALLUVIUM AND WHICH ARE ADJACENT TO FLOOD PLAIN OR TERRACE LANDFORM AREAS.

2. WATER AVAILABILITY CRITERIA:

   a. WATER IS AVAILABLE BY SURFACE-WATER IRRIGATION OR SUBIRRIGATION AND IS BEING, OR HAS SUCCESSFULLY BEEN, USED TO ENHANCE PRODUCTION OF AGRICULTURALLY USEFUL VEGETATION; OR

   b. SURFACE WATER IS AVAILABLE AND COULD BE USED TO ENHANCE PRODUCTION OF AGRICULTURALLY USEFUL VEGETATION.

Initial Identification Study of Alluvial Valley Floor

As previously noted, initial studies can be used by agencies interested in land use planning or leasing evaluation and by companies

interested in initial mine planning. The purpose of an initial identification phase is to permit identification of areas which clearly are <u>not</u> alluvial valley floors, so that detailed studies can be focused only on areas which might reasonably be expected to be alluvial valleys. The other purpose of initial studies is to permit a level of identification on the basis of readily available or easily collected data.

The final result of the initial study programs would be identification of areas which clearly are alluvial valleys, areas which clearly are not alluvial valleys, and areas of uncertain status. The use of readily available or easily collected data means that these data usually should not be plotted on maps of a scale larger than 1:24,000.

Depending on the outcome of these studies, the mine operator, for instance, can focus detailed studies on other regulatory issues, begin detailed characterization of the essential hydrologic functions of an alluvial valley floor, or collect more detailed data on those areas of uncertain status.

The following steps (table 2) are suggested to the applicant in conducting an initial investigation of alluvial valley floors:

<u>A. Regional evaluation of agricultural practices</u>. Before beginning a site-specific evaluation of the mine area, it is important

to understand the style of agricultural land use in an area, and the way, if there is one, that stream valleys are important to agriculture.

TABLE 2

COMPONENTS OF INITIAL IDENTIFICATION STUDY

1. Regional evaluation of agricultural practices.
2. Establish mine site study area.
3. Determine water availability.
   - A. Map presently irrigated lands.
   - B. Map all lands which appear to have the capability of being flood irrigated.
   - C. Map subirrigated areas.
4. Map areas meeting geologic criteria.

As previously noted, if certain stream valleys do not serve a special role in agricultural land use in a particular coal region, or if their special role is not a function of water availability, then these streams are not alluvial valley floors in that region. At least some types of stream valleys do play that special role in parts of each major coal region in the interior West, however.

The types of data that can be collected are illustrated in a case study in appendix D. Generally, the focus of these studies should be mapping flood irrigated and subirrigated areas and identifying the

style of agricultural water utilization in valleys. Within the region around the proposed minesite, the following kinds of data should be collected:

1. The types of streams and valleys developed for surface-water irrigation or spreader dike systems.

2. The physical characteristics of those valleys.

3. The role of subirrigated land in hay or crop production and grazing.

These data can later be used in assessing those valleys with the capability to be irrigated.

An attempt should be made to distinguish subirrigated areas that are agriculturally important in ranch management. Subirrigated, cropped areas are an obvious feature, and the size of these areas can be noted. More uncertain, however, is the pattern of use of subirrigated rangeland. During the regional agricultural land use evaluation, data can be collected on the kinds of subirrigated rangeland that are of some importance to ranchers. Some subirrigated areas may be too small, too narrow, or too difficult to reach to be reasonably used for grazing operations. Subirrigated areas of nonagriculturally useful vegetation do not qualify as alluvial valleys.

The Office of Surface Mining is presently collecting some of these types of data in its regional alluvial valley floor mapping program. Reports from this program will be available in early 1984.

B. Establish minesite study area. A mine permit application should identify alluvial valley floors and the impacts of proposed mining and reclamation operations within the proposed permit area and the area adjacent to the permit area. The "adjacent area" is a regulatory term definied as encompassing all areas which may be adversely affected by the proposed mine. The "adjacent area" and the permit area thus constitute the study area. For purposes of alluvial valley floor studies, identification of an adjacent area in terms of possible adverse impacts to ground-water and surface-water resources is necessary.

Regulatory authorities and industry often ask, "What area should a study encompass?" It is difficult to establish a regionwide standard for study area size because the geohydrology of Western mine areas differs widely. In conceptual terms, a study must encompass all areas possibly affected by proposed mining activities. This area of possible impact is defined at the application stage through analyses of ground-water, surface-water, geologic, and other environmental baseline data. Where an applicant does not have those kinds of data available at the time of the initial alluvial valley floor studies, information about adjacent area size at nearby mines and conversations with the regulatory authority can be used to establish the study area size.

Although it is clearly at the discretion of the applicant to choose an appropriate study area, it is obviously to the applicant's

benefit to initiate study on any lands which reasonably might be included in formally designated adjacent areas.

C. Water Availability. The following steps can be completed in any order:

1. Map all presently irrigated lands. These lands may already have been identified during the regional study, but if not, they should be identified and mapped within the study area. It is also helpful to identify the locations of diversions, ditches, dams, spreaders, and any other structures used to manipulate surface waters.

2. Map all lands which appear to have the capability of being flood irrigated. The capability of an area to be flood irrigated has been a difficult and sometimes controversial aspect of the identification process. Experience has shown the value of considering regional irrigation practices when considering site-specific irrigation capability. The applicant should try to answer the question, "Are the kinds of undeveloped stream valleys within the study area typically developed for irrigation elsewhere in the region?" If the answer is no, then the valleys in question within the study area can be rejected as alluvial valley floors.

Obviously, there is great latitude in the term "developed in similar type valleys". Valleys may be similar in terms of channel

character, incision, and basin area but differ in soil type or water quality. Valleys that appear at first notice to be similar to developed valleys may be shown to be dissimilar after further evaluation. At the initial study stage, the applicant will usually rely on easily collected data, such as channel character, size, slope, depth of incision, and basin area. However, more detailed data may be collected at the applicant's discretion. Factors considered in assessing irrigation capability are discussed more extensively in Appendix D.

Data concerning the success of presently abandoned irrigation structures is also helpful in assessing capability. Administrative decisions to date show a clear pattern of rejecting capability where abandoned irrigation systems clearly failed due to lack of water or poor quality water or soils.

One of the reasons for evaluating regional irrigation practices is that some western valleys have not been developed because of land ownership or water rights factors, and not the physical character of the valley. Administrative decisions show that in these situations, the capability of an area to be irrigated should be evaluated solely on physical characteristics.

3. <u>Map potentially subirrigated areas</u>. Subirrigation is another difficult and sometimes controversial topic. Its identificaton at the

initial study stage is usually dependent on color infrared air photo interpretation, which is available for all Western mine areas (appendix C). Well and soil moisture data which can confirm subirrigation is usually not available to the applicant at this stage. The interpretation of air photography in delineating subirrigation is discussed in appendix C.

The kinds (in terms of area and width) of potentially subirrigated areas that should be mapped should be based on the findings of the regional assessment, as well as on conversations with land managers of the immediate study area. The question often arises, "How small or narrow an area should I map?" The answer to this question is site specific to each region. Those potentially subirrigated areas that are viewed by the regional agricultural community as being important to grazing patterns should be identified. If there is consensus in a region that certain types of areas are too small to matter in grazing land use, or are characterized by unpalatable species, they need not be identified.

4. Map areas meeting geologic criteria. As already noted, aluvial valley floors are both a geologic and an agricultural water-use feature. Surficial geologic data (appendix A) should be collected and flood plain or terrace areas mapped. Areas overlain by slopewash or aeolian deposits, and which might reasonbly be expected to be underlain by alluvium, should be identified as areas of

uncertain status. Any areas meeting the geologic criteria which also meet one of the water availability criteria can be considered alluvial valley floors for purposes of initial identification.

Further Studies

Revised regulations of the Office of Surface Mining provide discretion to the applicant to request an alluvial valley floor status determination prior to formal permit application submittal. If such a request is made, the regulatory authority will make such a determination, based on the data presented and other data available. If the applicant adequately characterizes the regional agricultural use practices; describes the physical character of the study area, valleys, and stream channels; and interprets available color infrared photography, consistent with the previous section, the regulatory authority should be able to make an initial interpretation of alluvial valley floor status. If the applicant concurs with the initial determination, then the identification process can end.

In this case, the applicant can proceed with detailed studies appropriate for a permit application for those areas that are or might be alluvial valleys (chapter III). Areas of uncertain status can be resolved with detailed stratigraphic data for areas covered with slopewash or aeolian deposits. Areas that the applicant and regulatory authority agree do not meet geologic or water availability criteria can be eliminated from any alluvial valley floor related detailed studies.

However, disagreement between applicant and regulatory authority may arise, particularly with respect to water availability. Color infrared air photo interpretation will sometimes result in identification of areas whose water source to vegetation is not ground water. Development of wells, soil pits, and other studies discussed in appendix C would provide additional data to resolve this issue. Also, regulatory authorities and applicants may disagree on the interpretation of regional irrigation patterns in terms of the capability of study area streams for surface-water development. In this case, detailed studies of water yield, water quality, soil type, or other considerations in irrigation development (appendix B) should be conducted. Whatever the disagreement, the applicant and regulatory authority should agree on the points of contention and the studies needed to resolve the issue.

The identification phase should end when agreement is reached on status of all stream valleys in the study area. Precise boundaries of the designated alluvial valleys may not be drawn until other detailed data collected for the permmit application are submitted.

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CHAPTER III

PERMIT APPLICATION DATA SUBMITTALS

Introduction

If alluvial valley floors have been identified within the permit or adjacent area, certain types of data and analyses must be contained in the permit application. If the initial or further identificaton studies show that no alluvial valley floors occur in the study area, then the identifcation study data should be presented, or the negative determination written by the regulatory authority should be referenced. The data and analyses contained in the permit application for an operation affecting a designated alluvial valley floor should allow the regulatory authority to make a determination of:

1. The significance of the alluvial valley floor and its affected area of the agricultural activities of the farming operation [510(b)(5)(A)] and whether the operation would interrupt, discontinue, or preclude farming on a significant alluvial valley floor [510(b)(5)(A)].

2. The characteristics of the alluvial valley floor which are necessary to support its essential hydrologic functions during and after mining, and whether these essential hydrologic functions will be preserved and/or restored [515(b)(10)(F)].

3. Whether the operation will cause, or presents, an unacceptable risk of causing, material damage to the quantity or quality of surface or ground waters that supply alluvial valley floors signficant to farming [510(b)(5)(B)].

4. The effectiveness of proposed reclamation with respect to requirements of the Act (if mining is proposed) [515(b)(10)(F)].

5. The adequacy of proposed environmental monitoring designed to document compliance with alluvial valley floor performance standards during and after mining and reclamation operations [510(b)(5) and 515(b)(10)(F)].

In developing a detailed study plan, the applicant should keep in mind that the regulatory authority is under statutory requirement to satisfy certain questions and to make specific written findings. With this in mind, the applicant can develop an appropriate and efficient study program to provide the necessary data. The following section reviews these regulatory considerations.

The Question of Significance

The significance of alluvial valley floors to farming operations is a critical aspect of the regulatory process because the SMCRA exempts certain portions of an alluvial valley floor from the mining prohibition and hydrologic protection provisions of Section 510(b)(5)(A) and (B). The basis for these exemptions is that some land can be removed from agricultural production without adversely affecting agricultural operations. Undeveloped rangeland that is determined to be insignificant to a farming operation is one exemption; the other exemption allows disruption of a small acreage of a signficant alluvial valley floor. It is suggested that alluvial valley floors be assumed to be either significant or insignificant in the manner outlined below. With this basis, a regulatory decision

focuses on the area that can be disrupted while creating only a negligible impact on a ranching operation.

Alluvial valley floors having only the capability to be surface irrigated can be assumed to be insignficant and need not be evaluated further. All alluvial valley floors which are currently* flood irrigated or subirrigated are assumed to be significant. For these significant valleys, the central question to be addressed is: What constitutes an insignificant acreage whose loss would have negligible impact on the particular ranching or farming operation?

Negligible impact is based on the relative importance of vegetation and water of the alluvial valley floor to the individual farm's production. Some loss in production is acceptable, and the issue concerns the point at which losses cease to be negligible.

A simple way to consider negligible impact or significance is in terms of production, because production from alluvial valley floor lands can be compared to production for the rest of the farm. Production can be measured by tons of hay, by animal unit months (AUM's), by bushels of wheat, or by whatever main crop or livestock is produced. For example, in the State of Wyoming, all significance and

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*Currently, in this context, means the most developed level of irrigation in use on or after August 3, 1977.

negligible impact determinations are made in terms of AUM's. In parts of North Dakota, it might be more appropriate to make calculations in terms of bushels of wheat produced. Determining production is terms of monetary value is not recommended because of the annual fluctuations of farm product prices. In any case, only income or production from farm-related activities should be considered. Although comparing production is relatively simple, other factors which make alluvial valley floors important in specific situations should also be considered and may override a simple comparison of production. An example illustrates this point:

> A ranch in the Powder River Basin grows all its hay needed as winter feed for the ranch's herd of cattle. The hay is the only crop grown on the alluvial floor. The production of the hay crop can be compared to the vegetative production of the rest of the ranch's rangeland to determine relative importance, but this comparison would ignore the fact that the amount of hay grown for winter feed is the limiting factor on the size of the herd. Therefore, in determining the small, insignificant acreage of the hayed alluvial valley floor, comparison should be made of the hay production lost to the hay production remaining.

Negligible impact must be determined for each alluvial valley floor on the basis of the importance of portions of the alluvial valley floor to the specific ranching or farming operation to which a parcel belongs. Five acres of irrigated hayland may be significant to a small ranch, whereas 20 acres of similar land may not be significant to a much larger ranch. For regulatory purposes, an entire subirrigated undeveloped rangeland valley used only in summer may be

insignificant to a large operation. A farm is generally considered to be the combination of land units with acreage and boundaries in existence prior to August 3, 1977, or, if established or modified after this date, with those boundaries based on enhancement of the farm's agricultural productivity and not related to surface coal mine operations.

The kinds of data that can be collected in making a signficance evaluation are listed in table 3.

TABLE 3

KINDS OF DATA USEFUL FOR SIGNIFICANCE DETERMINATIONS

1. Information on total farm production:

   A. An inventory of typical livestock numbers.

   B. A cropland/hayland use summary for typical production and marketing years, including the following:

      (1) Acreage of each crop grown;

      (2) Yield per acre;

      (3) Total production harvested;

      (4) Estimated carrying capacity of aftermath (AUM's);

      (5) Disposition of crops (percentage);

         (a) Amount fed to farm's livestock; and

         (b) Amount sold.

   C. Acreage and estimated carrying capacity (AUM's) of the range and pasture resources of the farm under typical weather conditions, excluding crop production and carrying capacity of the crop aftermath.

2. Information for farm's developed lands within affected alluvial valley floor, including the following:

   A. Information as requested in 1.B. and C. above;

   B. A history of land uses and production; and

   C. Maps showing:

      (1) History of ownership/tenancy of the affected alluvial valley floor and adjacent lands.

      (2) History of land uses and management practices within and adjacent to the affected alluvial valley floor; e.g., fencing, irrigation structures, haylands, croplands, pasturelands, etc.

      (3) Extent of subirrigation.

      (4) Extent of affected alluvial valley floor.

Although the Office of Surface Mining has not adopted a regulatory definition of "negligible impact," the State of Wyoming has done so, and their approach may be useful in other States. The quantitative definition (table 4) was developed after numerous interviews were held in the State with ranchers concerning income cycles and acceptable losses. Although no loss of income is appreciated by an operator, the nature of agricultural business is one of cyclical trends of good and bad times. Some amount of losses are experienced occasionally as part of any operation. The State of Wyoming estimated a range of productivity losses depending on ranch size--from 3 percent for a very small operation to 10 percent for a large one--that operators considered sustainable without affecting their overall operation. In other words, ranchers were asked what amount of loss in productivity would really affect their overall operation.

The quantitative definition of negligible impact developed in Wyoming cannot automatically be transfered to other States. Acceptable losses in other regions may differ from the data for Wyoming. However, the process used by Wyoming to develop its definition is instructive and can be used by operators and regulatory authorities elsewhere in establishing threshold values for negligible impact.

As additional background on this issue, a review of regulatory decisions is helpful. In one decision in Montana, the regulatory

authority determined that a 2 percent loss in hay production measured in equivalent AUM's for an overwintering herd of 500 head was less than a negligible loss.

TABLE 4

WYOMING DEFINITION OF NEGLIGIBLE IMPACT

Where developed lands are involved in a proposed mining operation and where agricultural use of such developed lands would be interrupted, discontinued, or precluded during mining, the loss of such lands from a farm's production capabilities must be assessed. If it is determined that the loss to farm production would only cause a negligible impact upon total production, then a permit to mine may be granted. The equation of:

$$P = 3 + 0.0014X,$$

Where: P = productive loss in percent, and
X = number of animal units in excess of 100,

is used to estimate allowable farm production loss less than 10 percent. "P" (up to 10 percent) is the percentage of productive loss considered to be of a negligible impact to a Wyoming farm. The equation is a result of the following assumptions: (1) that a 3 percent loss in production to a very small viable farming operation (100 AU's) would constitute a production loss in excess of that which could be absorbed through management changes; and (2) that production loss which can be absorbed by viable farming operations will generally increase as total farm production must be converted to animal units. Any loss greater than 10 percent is considered to exceed a negligible impact to both small and large Wyoming farming operations.

Essential Hydrologic Functions

"Essential hydrologic functions" is a term used in the SMCRA [515(b)(10)(F)]. Mining and reclamation operations, in order to gain permit approval, must preserve the essential hydrologic functions of alluvial valley floors not proposed for mining and must restore the functions of valleys proposed for mining. The purpose of regulatory focus on essential hydrologic functions is to ensure that the goal of environmental protection or reclamation is met: restore or protect the <u>essential</u> hydrologic roles of the valley which give the valley its agricultural value. These roles include the collection, storage, and regulation of water flow which results in water being usefully available from streams or alluvial aquifers for agricultural purposes. Each alluvial valley floor in the West has unique characteristics, but the function of providing water for agriculture is common to all valleys.

Section 515(b)(10)(F) of the Act requires that the essential hydrologic functions of all alluvial valley floors be preserved during mining and reclamation operations. The term "preserve" is understood (based on legislative history) to have two meanings, depending on whether the alluvial valley floor is within or outside the affected area. For alluvial valley floors within the affected area, the term "preserve" means that the essential hydrologic functions must be reestablished during reclamation. For alluvial valley floors offsite, the essential hydrologic functions must be "preserved"--that is,

maintained--at all times. To allow the regulatory authority to make a determination that essential hydrologic functions will be maintained or reestablished, the hydrologic functions of the specific valley and the characteristics of the valley which create those functions should be identified. Every alluvial valley floor is unique, and the geologic, hydrologic, and biologic characteristics which combine to supply water for agricultural activities are unique.

Studies of essential hydrologic functions should focus on the unique character of a specific alluvial valley resulting in making surface water, ground water, or both usefully available to plants. Once the characteristics are understood, the operator can propose mitigation of impacts or a reclamation plan which restores the same functions, although not necessarily with the same characteristics. The degree of detail needed to describe each characteristic should be related to the likelihood of that characteristic being disturbed or affected and the importance of the characteristic to the basic functions. Most detail is required when the alluvial valley floor is proposed for mining and the reestablishment of the essential hydrologic functions must be accomplished.

It is impossible to give one study outline for all alluvial valley floors. In studying a specific valley, the important hydrologic functions should be broadly identified, and then the specific characteristics supporting each function should be identified

and defined. The functions and characterics of any alluvial valley floors will probably be a subset of those listed in table 5. Appropriate studies which can be carried out and included in a permit application are outlined in tables 6 and 7.

TABLE 5

ESSENTIAL HYDROLOGIC FUNCTIONS OF ALLUVIAL VALLEY FLOORS
AND FREQUENTLY OCCURRING CHARACTERISTICS RELATED TO THOSE FUNCTIONS

1. Typical characteristics supporting the function of collecting water:

   A. The amount and rate of runoff and a water balance analysis, with respect to rainfall, evapotranspiration, infiltration, and ground-water recharge.

   B. The relief, slope, and density of the network of drainage channels.

   C. The infiltration, permeability, porosity and tranmissivity of unconsolidated deposits of the valley floor that either constitute the aquifer associated with the stream or lie between the aquifer and the stream.

   D. Other factors that affect the interchange of water between surface streams and ground-water systems, such as depth to ground water, the direction of ground-water flow, and the extent to which the stream and associated alluvial ground-water aquifers provide recharge to, or are recharged by, bedrock aquifers.

2. Typical characteristics supporting the function of storing water:

   A. Surface roughness, slope, and vegetation of the channel, flood plain, and low terraces that retard the flow of surface waters.

   B. Porosity, permeability, water-holding capacity, saturated thickness, and volume of aquifers associated with streams, including alluvial aquifers, perched aquifers, and other water-bearing zones found beneath valley floors.

   C. Moisture held in soils or the plant-growth medium within the alluvial valley floor, and the physical and chemical properties of the subsoil that provide for sustained vegetation growth or cover during extended periods of low precipitation.

TABLE 5

ESSENTIAL HYDROLOGIC FUNCTIONS OF ALLUVIAL VALLEY FLOORS AND FREQUENTLY OCCURRING CHARACTERISTICS RELATED TO THOSE FUNCTIONS (Continued)

3. Typical characteristics supporting the function of regulating the flow of water:

   A. The geometry and physical character of the valley, expressed in terms of the longitudinal profile and slope of the valley and the channel, the sinuosity of the channel, the cross-section, slopes, and proportions of the channels, flood plains and low terraces, the nature and stability of the streambanks, and the vegetation established in the channels and along the streambanks and flood plains.

   B. The nature of surface flows as shown by the frequency and duration of flows of representative magnitude including low flows and floods.

   C. The nature of interchange of water between streams, their associated alluvial aquifers, and any bedrock aquifers as shown by the rate and amount of water supplied by the stream to associated alluvial and bedrock aquifers (i.e., recharge) and by the rates and amounts of water supplied by aquifers to the stream (i.e., baseflow).

4. Typical characteristics which make water available:

   A. The presence of landforms including flood plains and terraces suitable for agricultural activities.

   B. The presence of valley soils which support agriculturally useful species.

   C. The resistance of the valley to erosion by floods.

   D. The extended availability of surface and ground water.

TABLE 6

TYPICAL KINDS OF STUDY NECESSARY TO CHARACTERIZE ESSENTIAL HYDROLOGIC FUNCTIONS FOR PERENNIAL AND INTERMITTENT STREAMS WITH OR WITHOUT SUBIRRIGATED AREAS

1. Geomorphology:

   A. Map and describe the channel, flood plain, and terraces at a scale of 1" = 400'. Survey representative channel cross-sections at approximately 1,500-foot intervals. Determine meander characteristics.

   B. Map the surficial geology of the valley and describe the recent geomorphic history of the valley floor.

   C. Survey the longitudinal profile of the thalweg and the valley slope.

   D. Identify the texture of channel bed and banks, and describe bedforms, if present. Estimate channel roughness.

   E. Collect sediment samples and separate bedload and washload fractions.

2. Surface Water:

   A. Collect continuous streamflow records upstream and downstream from the affected alluvial valley floor. Estimate mean annual and monthly streamflow.

   B. Develop floodflow estimates, estimate stream velocities, and estimate inundated areas on surveyed cross-sections for the 2-, 10-, 25-, and 100-year floods.

   C. Collect streamflow records on tributaries affected by mining operations.

   D. Collect precipitation and snowfall data and relate it to stream hydrographs.

   E. Estimate runoff and sediment-yield contribution from mining areas to the alluvial valley floor.

   F. Measure and describe the water quality charcteristics of the valley floor stream and significant mining-affected tributaries.

TABLE 6

TYPICAL KINDS OF STUDY NECESSARY TO CHARACTERIZE ESSENTIAL HYDROLOGIC FUNCTIONS FOR PERENNIAL AND INTERMITTENT STREAMS WITH OR WITHOUT SUBIRRIGATED AREAS
(Continued)

3. Geohydrology: Geohydrologic studies for alluvial valley floors without subirrigated areas can be less intensive but the relationship between streamflow and aquifers must be determined.

   A. Identify the configuration, location, and strata of the alluvial aquifer and develop geologic cross-sections; use backhoe pits and drillhole data.

   B. Describe the capillary fringe for the different materials in which it is found.

   C. Map geology and structure of the study area and develop representative geologic cross-sections.

   D. Describe the connection of the alluvial saturated zone with adjacent aquifers.

      (1) Define potentiometric surfaces in all aquifers.

      (2) Perform pump tests to determine aquifer properties.

      (3) Identify faults or other hydrologic boundaries.

   E. Monitor alluvial ground-water levels within and adjacent to the alluvial valley floor to adequately define the dynamic interrelationship of the system.

   F. Describe seepage run to identify areas where streamflow is lost to, or gained from, the ground-water system.

4. Soils and Vegetation:

   A. Prepare a soil survey to develop an understanding of the characteristics of soils which make it irrigable or which permit subirrigation.

   B. Prepare a vegetation inventory, providing special attention to varying vegetation patterns on terraces, subirrigated areas, and cropland.

TABLE 7

TYPICAL KINDS OF STUDY NECESSARY TO CHARACTERIZE ESSENTIAL HYDROLOGIC FUNCTIONS FOR EPHEMERAL STREAMS WITH NO SUBIRRIGATED AREAS

1. Geomorphology:

   A. Map and describe the channel, flood plain, and terraces at a scale of 1" = 400'. Survey representative channel cross-sections at approximately 1,500-foot intervals.

   B. Map the surficial geology of the valley and describe the recent geomorphic history of the valley floor.

   C. Survey the longitudinal profile of the thalweg.

   D. Identify the texture of channel bed and banks. Estimate channel roughness.

2. Surface water:

   A. Collect streamflow records for the valley stream and tributaries affected by mining. Estimate peak flow and mean annual and monthly streamflows.

   B. Develop floodflow estimates, estimate stream velocities, and estimate inundated areas on surveyed cross-sections for the 2-, 10-, 25- and 100-year floods.

   C. Estimate runoff and sediment yield contribution from mining areas to the alluvail valley floor.

   D. Measure and describe the water quality characteristics of the valley floor stream and significant tributaries to be affected by mining.

3. Soils and Vegetation:

   A. Describe the characteristics of valley bottom deposits from backhoe pits.

   B. Prepare a soil survey to develop an understanding of why the soils are irrigable.

   C. Prepare a vegetation inventory, providing special attention to varying vegetation patterns on terraces and cropland.

Material Damage

Section 510(b)(5)(B) of the Act prohibits a mining operation from materially damaging the waters supplied to those alluvial valley floors signficant to agricultural operations. Material damage is defined in regulation as degrading or reducing water quantity or quality to the extent that changes would significantly decrease the capability of an alluvial valley to support agricultural use dependent on that water.

Thus, material damage to water supplies is to be evaluated in terms of the effect of that change on the usefulness of the area to agriculture and not merely in terms of a measured change in water supply or quality alone.

Analyses concerning material damage must obviously be predictive in nature, using baseline data collected to characterize essential hydrologic functions and the specific mining and reclamation plan proposals. The major difficulties in such an effort are (1) to predict change in hydrologic and other parameters, and (2) to estimate the effect of those changes on agricultural use. The kinds of changes which might be considered in a material damage assessment are listed in table 8. The kinds of predictive studies which should be considered in a material damage assessment are listed in table 9.

As with "negligible impact" (the term of importance when deciding how much land can be disturbed by mining), material damage must be

quantified in terms of the degree of acceptable change. There is a threshold, below which change is considered acceptable and above which is considered material damage.

Although quantitative regulatory standards for material damage have not been proposed, consistency dictates that threshold numbers developed for negligible impact analyses are appropriate for material damage assessments. In other words, if a predicted decrease in agricultural usefulness of an alluvial valley (such as a decrease in productivity, as measured in AUM's) due to mining-induced impacts would be considered neglible under a significant evaluation, then material damage would not occur.

The guidance offered in developing threshold numbers for significance determinations applies in this case. The State of Wyoming has offered specific guidance in this topic, whereas other States have developed more fluid standards. In States without fixed standards, interviews with ranchers and farmers in the region can help fix an "acceptable-loss" threshold value.

TABLE 8

POSSIBLE HYDROLOGIC CHANGES WHICH MIGHT MATERIALLY DAMAGE AGRICULTURAL ACTIVITIES ON ALLUVIAL VALLEY FLOORS

1. Diversion or alteration of streamflow of valley stream or tributaries.

2. Change of runoff characteristics of affected land in drainage basin.

3. Change of streamflow through mine area due to evaporation or dewatering.

4. Reduction of sediment load caused by impoundments.

5. Increase in sediment yield from reclaimed lands.

6. Disruption of the alluvial aquifer or other aquifers hydraulically connected to the alluvial aquifer.

7. Drainage of the alluvial aquifer to an adjacent mined area.

8. Alteration of the water quality of the stream or alluvial aquifer due to surface discharge, seepage, or ground-water movement.

TABLE 9

PREDICTIVE STUDIES FOR MATERIAL DAMAGE ASSESSMENTS

1. Hydrologic Assessment:

   A. Drawdown analysis for each aquifer in or adjacent to a mine pit.

   B. Model ground-water flow patterns for mining and postmining periods, given the estimated changes in aquifer characteristics.

   C. Model streamflow for mining and postmining periods, given the estimated changes in drainage density, runoff characteristics, drainage area, and channel characteristics of the reclaimed area.

   D. Estimate postmining ground-water quality of spoils water and determine effect on adjacent surface and ground waters.

   E. Estimate postmining surface-water quality of streams draining the reclaimed area and determine effect on adjacent surface and ground waters.

   F. Develop a water balance of the entire study area encompassing the cummulative effects of the studies mentioned above.

2. Vegetation and Agricultural Assessment:

   A. Compute loss of irrigated acreage due to reduced streamflow.

   B. Estimate reduction in crop yield due to degraded water quality.

   C. Estimate loss of productivity of subirrigated species due to lowered water table.

   D. Estimate loss of agricultural land due to a rise in the water table.

Reclamation of Alluvial Valley Floors

Reclamation of alluvial valley floors should be approached with the intent of reestablishing the essential hydrologic functions of the original alluvial valley floor. Commonly, reestablishing these functions can be accomplished most completely by restoring all components of the valley floors to their preexisting condition. In reality, it is not always possible to do this, and alternate design of some components is necessary owing to the drastic disturbance of the original alluvial valley materials. The test of reclamation success is whether the functions of the valley are reestablished.

A good understanding of the characteristics of the existing, undisturbed system is a prerequisite to developing the plan. Appendix E discusses concepts in reclamation related to flood irrigation and subirrigation. Obviously, for flood irrigation, the major focus of reclamation is on the stream channel, the availability and quality of surface water, and the topography and soil characteristics of areas to be irrigated. Stability of the reclaimed stream channel is of primary concern, and, as discussed in appendix E, a geomorphic approach to reclamation planning is encouraged to ensure stability of the valley floor over the long term.

For subirrigated valleys, the characteristics of the reconstructed aquifer, the volume and quality of the restored ground water, its annual fluctuations, the nature of the reestablished

vegetation communities, and their expected productivities are all issues which must be addressed. The science of aquifer reconstructon is in its infancy; therefore, less guidance can be given in appendix E for reclamation of subirrigated valleys than is given for stream channel reclamation. Perhaps of most value to the reclamation planner is the discussion of proposed reclamation plans for subirrigated valleys.

Developing a Monitoring System

Ongoing monitoring programs must be proposed at the time of permit application submittal. The monitoring program is designed to demonstrate compliance with the performance standards of the SMCRA. Monitoring studies are usually continuations of some of the studies undertaken in the considerations of significance, material damage, essential hydrologic functions, and reclamation. The level of monitoring of various aspects of an alluvial valley floor will depend on the degree of importance of the agricultural lands and the sensitivity of the agricultural or hydrologic systems to effects of mining. Some or most of the monitoring requirements needed for alluvial valley floor protection will probably be the same as those required by other regulations concerning hydrologic protection. The following phases of a monitoring program should be considered:

1. Continuation of baseline studies. Frequently baseline monitoring initiated for studying alluvial valley floors would be continued during the permitting and initial mine development periods. Although an understanding of the agricultural and hydrologic systems of an alluvial valley

floor must be developed for a permit application, longer term records can provide a better understanding of such factors as seasonal variation. This greater knowledge can help clarify the meaning of later monitored changes in the alluvial valley floor system and can aid reclamation planners to "fine tune" valley floor or alluvial aquifer reconstruction plans.

2. Monitoring during mining. Most important during mining is the monitoring of the essential hydrologic functions and agricultural utility of the alluvial valley floor to document that protected valley floors remain unaffected.

3. Monitoring after mining. Monitoring of protected alluvial valley floors must continue after mining because of the commonly significant hydrologic changes which occur as ground- and surface-water systems readjust to the cessation of mining operations. Additional monitoring must be started to demonstrate compliance of reclaimed alluvial valley floors with appropriate performance standards.

It is best for the applicant to discuss these studies with the regulatory authority to determine which studies ought to be continued during and after mining and reclamation.

APPENDIX A

ALLUVIAL DEPOSITS AND GEOMORPHOLOGY

Introduction

Alluvial valley floors are composed of "unconsolidated stream-laid deposits" but are not composed of "upland areas which are generally overlain by a thin veneer of colluvial deposits" (30 CFR 701.5). Virtually all stream valleys in the semiarid and arid West are filled with unconsolidated deposits, and, thus, most stream valleys meet this criterion. The task of the geologist mapping alluvial valley floors is to map the areal and vertical extent of these deposits, describe their characteristics and make interpretations of their origin.

Collectively, the unconsolidated deposits of Western valleys are called valley fills. The deposits are actually composed of the debris left by several processes, such as streamflow, slopewash, wind, and/or landsliding. These processes also shape the valley floor, and recognition of particular landforms--terraces, flood plains, alluvial fans, for example--aids the geologist in describing the underlying deposits. Thus, the task of the geologist, in terms of the alluvial valley floor issue, is to identify those deposits and landforms whose origin is a function of streamflow. This appendix gives an overview

of the current state of knowledge about unconsolidated stream-laid deposits in the interior West, as well as a summary of geomorphic principles applicable to reclamation planning for those valley floors proposed in mining.

As emphasized in this section, identificaton of deposits and landforms related to stream, or fluvial, processes is not always clearcut, particularly at the margins of the valley. The quickest way to identify alluvial deposits is through mapping of stream terraces and flood plains. The easiest type of alluvial deposit to recognize, either in an outcrop or in drill cuttings, is gravel or well-sorted sand. However, older stream terraces may be masked by a mantle of colluvium, and some fine-grained alluvial deposits are indistinguishable from other unconsolidated deposits. Therefore, when questions arise concerning the lateral extent of stream-laid deposits, various types of evidence need to be evaluated bv a qualified geologist or geomorphologist.

Alluvial Deposits

Several classifications of alluvial deposits have been proposed (Fisk, 1947; Allen, 1965), and that outlined by Happ and others. (1940) is reviewed here. These authors recognized six types of deoosits which may underlie the alluvial floor of a valley (fig. A-1):

1. Channel fill deposits are primarily bed-load materials.
2. Vertical accretion deposits consist largely of suspended load materials and are deposited from overbank floodflows.

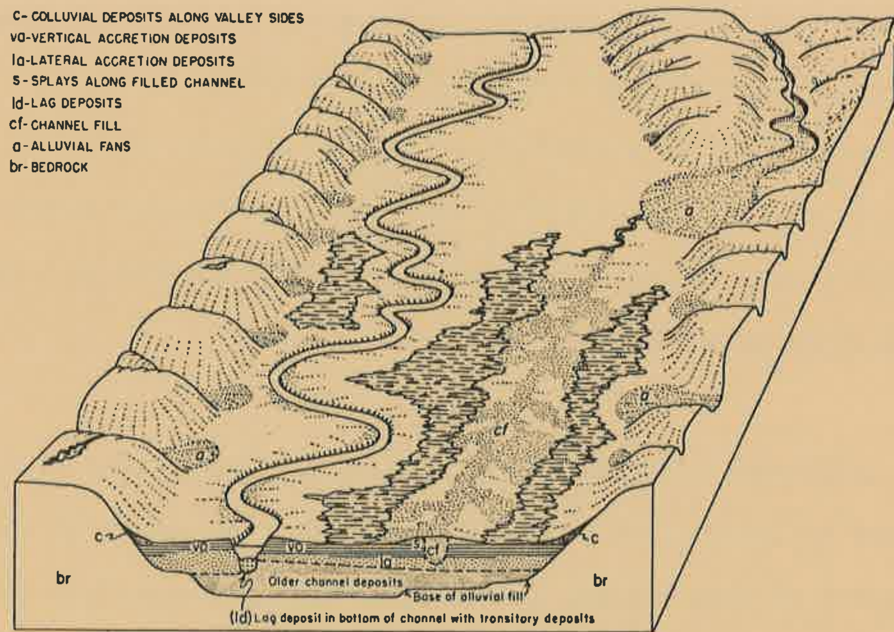

Fig. A-1 Types of alluvial deposits. (After Happ and others, 1940; Thornbury, 1969).

3. Flood plain or crevasse splay is a term applied to deposits spread over the flood plain through a restricted low section, along distributary channels, or through breaks in natural levees.

4. Lateral accretion deposits, such as point bar materials, occur at the sides of channels as channels migrate laterally.

5. Lag deposits are coarse materials which have been sorted out and left behind on the streambed.

6. Colluvium deposits consist of debris carried by slopewash and small rills into the valley. Such material is generally unsorted.

Typically, coarse-grained materials, such as gravel, make up the channel fill and lag deposits, whereas the vertical and lateral accretion deposits are generally finer grained. However, differentiation of the origin of various alluvial deposits cannot be made solely on the basis of grain size. Sedimentary structures and features seen in cross-sections of the deposits provide a better understanding of origin.

Different river flood plains have varying amounts of deposits formed by lateral and vertical accretion. The fact that flood plain deposits of many streams in subhumid areas are comprised mostly of silt with a thin, irregular layer of basal gravel has led some observers to believe that flood plains are comprised principally of overbank deposits (Stene, 1980; Schumm and Lichty, 1963; Everitt, 1968). Paleosols and cultural horizons found within the upper, fine-grained alluvium indicate that overbank deposition is responsible for alluvium above these horizons. Wolman and Leopold (1957),

however, were of the opinion that vertical accretion deposits make up only a minor component of most flood plain deposits chiefly because the continued lateral shifting of the channel eliminates areas with overbank deposits. Geologists should be aware that the stratigraphy of stream-laid deposits varies from stream to stream.

The types of alluvial deposits discussed above are generally better developed and more easily distinguishable on perennial streams. Ephemeral and intermittent streams tend to have poorly developed alluvial deposits owing to the varying size of runoff events responsible for transporting and depositing the sediment. In the semiarid West the alluvium underlying ephemeral drainages is usually a heterogeneous mixture of sediment ranging from gravel to fine clay (Hadley and King, 1978).

Terrace Formation

The most distinctive landforms showing stream processes are the terrace and the flood plain. Stream terraces are flat surfaces along the valley sides of stream courses marking the level of former valleys (fig. A-2). They are vestiges of former flood plains formed by streams which were higher in elevation than the present stream. The flat floor of a valley is constructed by the stream during lateral migration of the stream channel(s). As the stream simultaneously erodes one bank and deposits sediment on the other, older landforms are elmininated, and the new flood plain is built. At some time in

Fig. A-2 Terraces along Dutch Creek, near Sheridan, Wyoming. The flat-lying terraces in the valley bottom are haylands, and the valley slideslopes (foreground) are planted in small grains.

Fig. A-3 Flood plain and terraces of the Powder River near Arvada, Wyoming. The flood plain extends between the trees on both sides of the river.

the past, the stream has occupied each and every position on the flat valley floor.

A stream's flood plain (fig. A-3) is developed in response to the relative rates of transport of both water and sediment. The longer these rates remain fairly uniform through time, the broader the flood plain becomes as the stream migrates laterally. A change in climatic or watershed conditions which alters the water or sediment availability in the drainage basin can result in net aggradation or downcutting by the stream as the stream creates a new valley flat or flood plain at an elevation appropriate for the new conditions. In such a circumstance, the flood plain level previously associated with the stream is either abandoned by downcutting or is covered as aggradation occurs. During downcutting, the previous flood plain is dissected, and portions may remain as continuous benches bordering the stream, or, more often, as remnants of flat, or nearly flat, spurs jutting into the valley. Sediment deposited by aggrading streams covers older landforms and masks the former flood plain position.

A valley floor may contain several different terrace levels. The erosional and depositional history of terraces can usually be deciphered by looking at the geology of the underlying deposits. Figs. A-4 and A-5 diagram various scenarios of terrace development.

The progressive sequence of channel migration and consequent flood plain construction is portrayed in fig. A-6. The coarsest

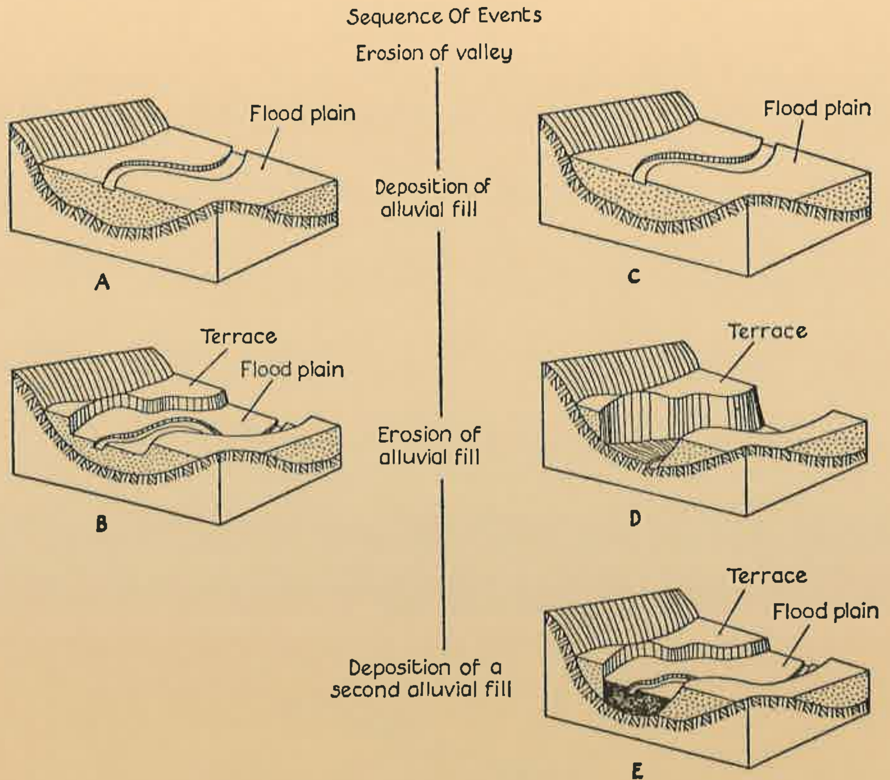

Fig. A-4 Block diagrams illustrating the stages in development of a terrace. Two sequences of events leading to the same surface geometry are shown in diagrams A, B, and C, D, E, respectively. (Leopold, Wolman, and Miller, 1964.)

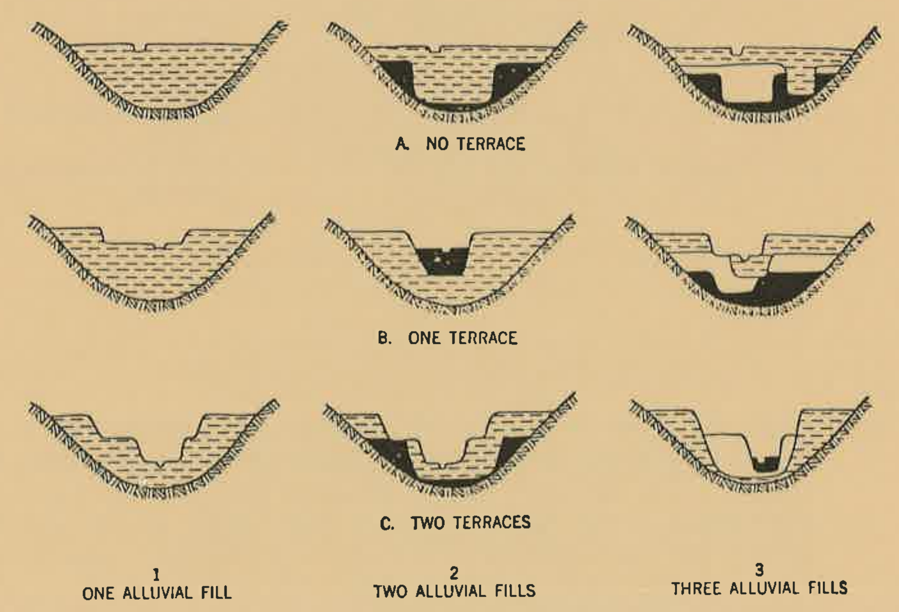

Fig. A-5 Examples of valley cross-sections showing some possible stratigraphic relations in valley alluvium. A, No terrace. B, One terrace. C, Two terraces. (Leopold, Wolman, and Miller, 1964.)

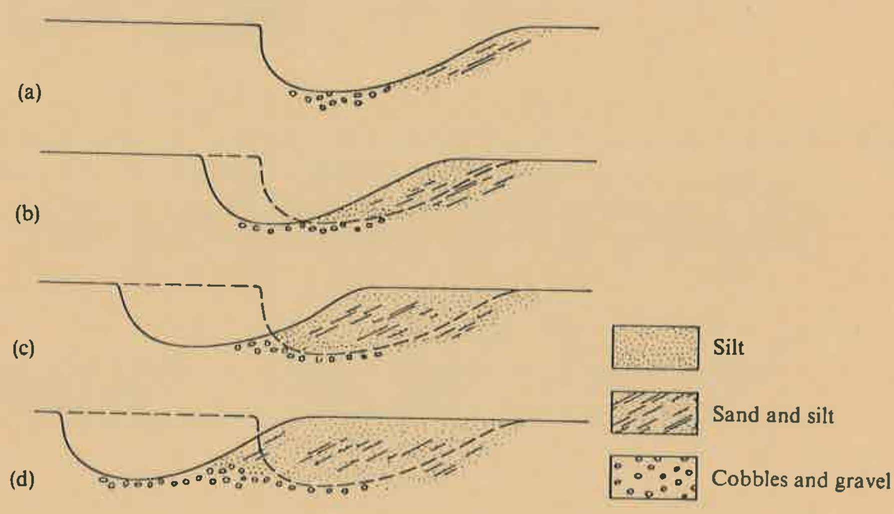

Fig. A-6 Four sequential stages in progressive construction of a flood plain as stream moves laterally, diagrammatically shown. (a) Initial stage showing gravel and sand on streambed. (b) Stream erodes left bank as it deposits on point bar to right of diagram. (c) Later stage showing streambed gravel covered over with sand and silt, finer material deposited near the top of the point bar. (d) Still later stage indicating how progressive lateral movement builds flood plain with cobble or coarse material at base and finest material near surface. (Dunne and Leopold, 1978.)

material, usually gravel, is deposited only on the channel bed. This coarse bed material tends to be covered with finer sand and silt which forms the channel bank. Deposition of additional fine-grained material occurs on top of the flood plain as overbank deposits during floods. As the material in the channel bed and banks is continually eroded from one bank, transported downstream, and redeposited on another, the characteristic features of unconsolidated stream-laid deposits or alluvium which underlie terraces and flood plains are created.

Flood plains and terraces generally tend to have flat surfaces; however, portions which are near valley sides are subject to local deposition of slopewash, and, therefore, the flat surface tends to curve upward to meet the valley side. This process occurs not only after formation of the flat flood plain or terrace but also during the depositional buildup of a flood plain. Sediment eroded from valley sides is deposited in the valley by local wash, tributary rills, and mass movement. These slopewash deposits are called colluvium and, in some cases, may be preponderant in the valley fill. In summary, flood plains and terraces have flat surfaces which are blurred at edges where they merge gradually with valley-side colluvium.

Alluvial Fans

In some valleys alluvial fans must be distinguished from stream terraces, particularly where a smaller valley joins a larger valley or large basin. Alluvial fans form where a stream, heavily loaded with

sediment, emerges from highlands onto a lowland (fig. A-1). At this juncture, there is a significant change in gradient, which reduces the stream's capability to transport sediment. The deposited sediment typically accumulates in a semicircular area with the coarser material at its head and the finer material downslope. The down-fan profile of an alluvial fan is typically concave, whereas the cross-fan profile is convex. A series of adjacent fans may, in time, coalesce to form an extensive piedmont surface or bajada. Alluvial fans are generally underlain by gravelly detritus that is poorly sorted and stratified and that usually do not contain deposits comparable to overbank or vertical accretion deposits of flood plains.

Difficulty has been encountered in some alluvial valley floor studies in distinguishing alluvial fans from stream terraces. If at the junction of two streams, the main stream can transport the entire sediment load of the tributary, no alluvial fan forms. Rather, the current flood plains of both streams are graded to each other. Similarly, terraces (former flood plains) tend to be graded to each other. Remnants of terraces along valley margins can be recognized and distinguished from alluvial fans because the terrace remnant is part of a terrace level mappable along the valley, because the underlying deposits do not vary in grain size in a direction perpendicular to the valley wall, and because of the surface morphology of the terrace.

Alluvium and Colluvium

As already noted, alluvial valley floors are those portions of topographic valleys underlain by stream-laid deposits. Geologists use the term alluvium to describe these kinds of deposits. To the geologist, colluvium is "a general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity" (American Geological Institute, 1974). Colluvium may be found in valley floors, but its identification is only possible if differences can be recognized between the material in transport in the stream and in transport on the slopes. Detailed stratigraphic data is also necessary.

As with most regulatory exercises, it becomes necessary to establish boundaries, even where natural processes have yielded gradational change. Colluvium is not always easily differentiated from alluvium in a field situation. Some key indicators in specific instances may provide the necessary distinctions; however, in other cases, the two deposits may not be readily distinguishable. In their work on alluvial valleys of eastern Wyoming, Leopold and Miller (1954, p. 13) stated that "alluvial terraces * * * characteristically do not exhibit a sharp textual break between deposits of the main stream and slopewash. In fact, the materials are generally so nearly identical that the criteria usable in the Big Horn Basin (Mackin, 1937) cannot be applied" (in our study).

The typical stratigraphy of alluvium in smaller drainages of the Powder River Basin and elsewhere is basal gravels overlain by silt and clay material. The fine-grained deposits tend to be more extensive laterally than the gravels. The gravels can be as much as 40 feet thick, with the total alluvium thickness ranging up to 70 feet. The great thickness and sorted nature of the gravel deposits clearly indicate their fluvial origin. Therefore, a map showing the extent of the basal gravel in the valley fill often indicates the minimum extent of alluvial deposits in the valley.

Fine-grained alluvial and colluvial deposits, however, are difficult to distinguish. Both are generally composed of clay, silt, and sand. Distinguishing features of alluvium are sometimes rounded particles and massive layering, with the stratigraphy less variable and the units thicker than in colluvium. Colluvium can have more angular grains and, where it has been transported along a slope by sheetwash, can be more thinly bedded with more variable stratigraphy. These features are relative and are not absolute guides to differentiating the deposits. Deposits may be distinguished by finding distinctive rock types in the deposit which could have been transported to the valley fill by only the stream or by only slopewash processes.

The deposits are generally examined in backhoe pits or as they are retrieved during a drilling operation. Neither method is ideal and does not offer as good a view of the deposits as that offered in

stream or roadcuts. Lithologic descriptions of drill cuttings do not indicate the type of lateral stratification of the deposits and vertical stratification can be partially or completely masked owing to mixing of the cuttings during drilling. Backhoe pits seldom exceed 15 feet in depth and, therefore, may not intersect deeper alluvial deposits.

Given the difficulty in distinguishing the two types of deposits, the geologist must use not only the evidence afforded by the deposits but also the evidence provided by the landform. Emphasis on landform data has been made by regulatory authorities because such data are more easily collected. As a general rule, all unconsolidated deposits beneath terraces and flood plains are considered to meet the criteria of an alluvial valley floor. Uplands, such as the middle and upper portions of hillslopes, are clearly not alluvial valley floors. Along the margins of valley floors, where the land surface slopes gently upward and underlying deposits are unconsolidated, the geologist must use all available evidence in determining the extent of alluvial deposits. The data for such distinctions are usually not available until the formal permit application stage.

Surficial Geologic Mapping

The U.S. Geological Survey has mapped surficial geology of Campbell County, Wyoming, at a scale of 1:100,000 (Reheis, 1982; Reheis and Coates, 1982; Reheis and Williams, 1979) and has also

mapped much of the county at a scale of 1:24,000 (fig. A-7). This effort represents the most comprehensive surficial mapping program in a Western coal region, and the data collected in this effort are very useful in initial alluvial valley floor identification studies. Table A-1 lists the mapping units used in the study, as well as deposit description, common thickness, origin, typical landscape position, and common slope. Those mapping units which meet the geologic criteria of alluvial valley floors are flood plain alluvium (fa), stream terrace alluvium (ta), and minor stream alluvium (aa). It is also possible that portions of the sheetwash alluvium (sa), fan, apron, pediment, and sheetwash alluvium (fs), and dune sand and windblown silt (ed) mapping units are underlain in part by alluvium, where these deposits are adjacent to alluvium-filled valleys.

Fig. A-8 shows a portion of the Turnercrest NE quadrangle and indicates of those mapping units or portions of mapping units which may meet the geologic criteria for purposes of initial identification.

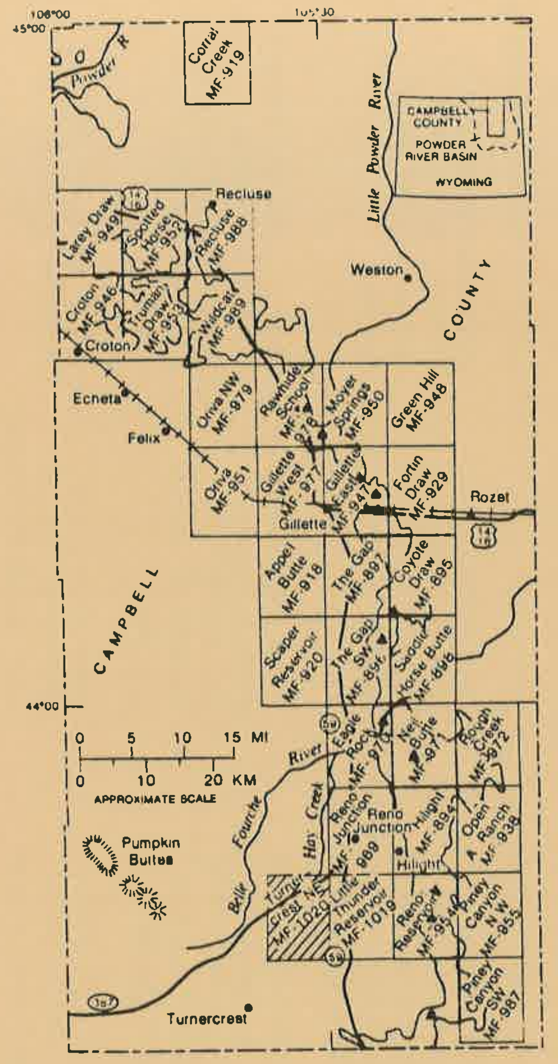

Fig. A-7 Index of recently published U.S. Geological Survey surficial geologic maps in Campbell County, Wyoming. Approximate area of strippable coal shaded (Keefer and Schmidt, 1973). Triangles indicate active or proposed coal strip mines.

TABLE A-1

CHARACTERISTICS OF MAP UNITS

(Used on U.S. Geological Survey surficial geologic maps in Campbell County, Wyoming)

Symbol, name, and age of unit	Materials	Origin	Typical position in the landscape	Common thickness (feet)	Common slope (percent)
		ALLUVIAL DEPOSITS			
fa FLOOD PLAIN ALLUVIUM (HOLOCENE)	Sand and silt, locally containing bedded clay or fine gravel. Isolated pebbles and cobbles of sandstone, porcellanite, and ironstone common locally.	Stream channel and overbank deposits in areas that are flooded.	Channel and flood plain of major stream. May include parts of lowest terrace.	5-10	0-2
ta STREAM TERRACE ALLUVIUM (HOLOCENE)	Massive to well-bedded sand, silt, and clay containing rare thin gravel beds and widely scattered pebbles, most of which are porcellanite.	Stream channel and overbank deposits that are now above the level of stream flooding.	Terraces (benches) along a major valley bottom above the usual level of flooding and below the	5-25	0-2
aa MINOR STREAM ALLUVIUM (HOLOCENE)	Silt and sand locally inter-bedded with clay or gravel. Isolated pebbles and cobbles of porcellanite, sandstone, and ironstone common locally.	Stream channel and overbank deposits of small ephemeral streams; may include flood plain sediments, deposits on low terraces, and sheet-wash alluvium.	Valley bottom of small ephemeral streams.	1.5-10+	0-4

TABLE A-1

CHARACTERISTICS OF MAP UNITS--CONTINUED

Symbol, name, and age of unit	Materials	Origin	Typical position in the landscape	Common thickness (feet)	Common slope (percent)
		ALLUVIAL DEPOSITS			
sa SHEETWASH ALLUVIUM (HOLOCENE)	Mostly reworked local debris from higher parts of slopes. Consists of poorly sorted to well-sorted irregularly bedded to laminated sand, silt, and clay, and minor interbeds of fine gravel.	Sediments deposited chiefly by overland flow of unchanneled water (sheetwash) in nearly level areas.	In swales and depressions, commonly adjoining ephemeral lakes or ponds.	1-5	1-4
fs FAN, APRON, PEDIMENT, AND SHEETWASH ALLUVIUM (HOLOCENE)	On alluvial fans and aprons the upper 1-5 ft is massive to faintly bedded sheetwash alluvium, similar to unit sa, grading downward into poorly sorted to well-sorted sand and silt containing small beds of angular to subangular gravel.	Deposited by ephemeral streams and sheetwash either as a buildup of sediment (alluvial fan or alluvial apron deposits) or as a thin discontinuous deposit on an erosional surface (pediment alluvium).	Gentle to moderate slopes between valley bottoms below and steeper slopes above.	3-10	1-5
		LAKE AND POND DEPOSITS			
lc LAKE AND POND SEDIMENTS (HOLOCENE)	Generally massive gray clay and silt; no pebbles. Some deposits are alkaline.	Sediments deposited in ephemeral lakes and ponds formed in depressions eroded by wind.	Locally low-lying parts of flat to rolling terrain.	3-15	0-1

TABLE A-1

CHARACTERISTICS OF MAP UNITS--CONTINUED

Symbol, name, and age of unit	Materials	Origin	Typical position in the landscape	Common thickness (feet)	Common slope (percent)
		WINDBLOWN DEPOSITS			
ed DUNE SAND AND WINDBLOWN SILT (HOLOCENE)	Crossbedded, parallel-bedded, or massive well-sorted to poorly sorted, mostly medium and fine, generally arkosic sand; locally coarse sand. Includes some windblown silt (loess).	Windblown sand with dune form preserved; commonly includes minor beds of windblown silt.	Small patches on uplands and in some valleys.	1.5-15+	0-15
		RESIDUAL DEPOSITS			
rW RESIDUUM ON WASATCH FORMATION (HOLOCENE AND (PLEISTOCENE?)	Generally sandy and silty material containing variable amounts of clay. Uper 1-3 ft may include a well-developed soil. Grades downward into unweathered Wasatch Formation. Upper 3 ft generally includes minor amounts of sheetwash alluvium, windblown sand and silt, and colluvium.	Products of in-place weathering of Wasatch Formation (Tw). On slopes sheetwash and soil creep move some material downhill. In most places wind periodically erodes and redeposits meterial of the upper 1-4 in.	Moderately to steeply rolling terrain.	3-15+	0-15

TABLE A-1

CHARACTERISTICS OF MAP UNITS--CONTINUED

Symbol, name, and age of unit	Materials	Origin	Typical position in the landscape	Common thickness (feet)	Common slope (percent)
		MIXED DEPOSITS			
Rs RESIDUUM AND SHEETWASH ALLUVIUM (HOLOCENE AND PLEISTOCENE?)	Residuum (rW) and sheetwash alluvium (sa). Mapped where boundaries are indistinct or cover of slopewash alluvium (sa) over residuum is thin and discontinuous.	See origin of residuum (fW) and sheetwash alluvium (sa).	Gentle lower slopes of hills.	1-10	2-10
cr COLLUVIUM AND RESIDUUM (HOLOCENE AND PLEISTOCENE?)	Colluvium generally consists entirely of unsorted and crudely bedded to massive sand, silt, and clay; may contain isolated angular to rounded pebbles, cobbles, and boulders; may be very stony, or may be mainly chaotic rubble; reflects composition of local bedrock.	Colluvium is bedrock debris, weathered bedrock, and soil that have been transported significant distances on moderate to steep slopes chiefly by downmass-wasting processes. Residuum has not been transported.	Steep upper slopes of hills a capped by baked and fused bedrock and coal ash (bf).	3-20	10-75
re RESIDUUM AND LOESS (HOLOCENE AND PLEISTOCENE?)	Residuum (fW) and windblown sand and silt (ed). Mapped where windblown sand and silt forms a thin discontinuous cover over residuum (rW).	See origin of residuum and windblown deposits (ed).	Gently rolling terrain.	3-15+	0-5

TABLE A-1

CHARACTERISTICS OF MAP UNITS--CONTINUED

Symbol, name, and age of unit	Materials	Origin	Typical position in the landscape	Common thickness (feet)	Common slope (percent)
		BEDROCK			
bf BEDROCK AND FUSED BEDROCK AND COAL ASH	Mostly baked shale and siltstone (porcellanite) that is hard, dense, and mostly brick red to bright orange but locally white or gray mottled with green. In some places rock has melted, forming a black bubbly rock (buchite) that is glassy and resembles some volcanic rocks. Buchite forms veins, flows, and chimneys with porcellanite. The coal ash (clinker) is gray or white and is generally 2 in. to 2 ft thick at the base of or within a porcellanite zone.	Bedrock has been baked and fused by near-surface burning of coal beds in the Wasatch Formation. Thick coal beds have burned hundreds of feets back from the outcrop, producing large areas of baked and fused bedrock and coal ash.	Hilltops and low hummocks.	10-30+	5-50
Tw WASATCH FORMATION	Drab-brown and gray claystone and siltstone containing thick lenses of sandstone.	Deposits laid in streams, swamps, and lakes.	Steeper slopes and ridgetops.	0-200	0-40

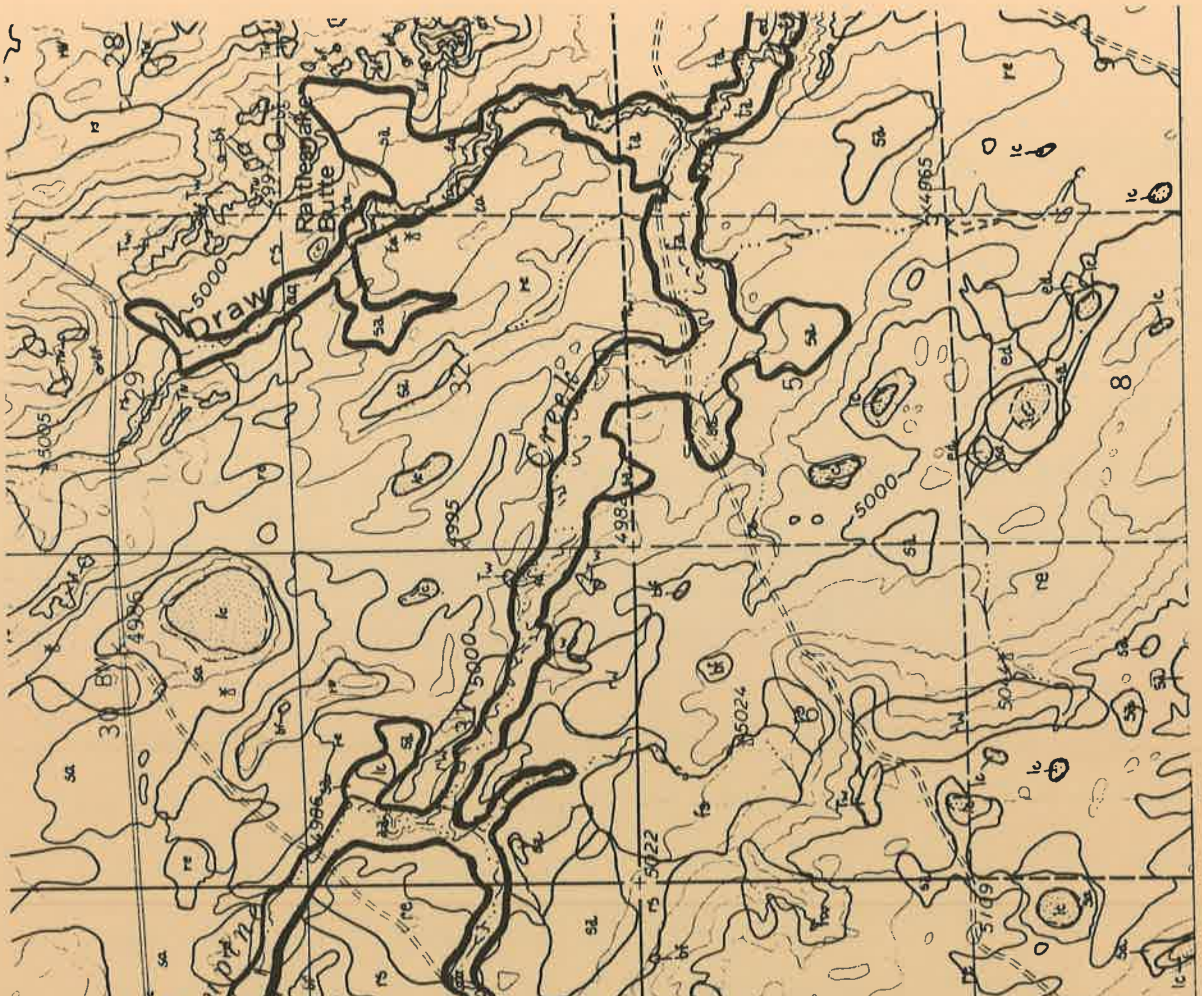

Fig. A-8 A portion of the surficial geologic map of the Turnercrest NE 7 1/2' quadrangle (Wyoming). Heavy lines indicate those mapping units of table A-1 which may include unconsolidated stream-laid deposits. Geology by D. A. Coates. Map scale is 1:36,000.

Bankfull Characteristics of Streams

The physical characteristics of streams are of interest in terms of alluvial valley floors as an aid to estimating hydrologic characteristics of ungaged streams and as an aid in developing reclamation plans for stream channels. The first is discussed briefly in appendix B and the latter in appendix E. This section discusses baseline identification of physical channel characteristics and some other uses of that data.

The identification of channel size characteristics is important because it is generally assumed that channel size is a function of the flows which occur in the channel, particularly a formative or dominant discharge to which other flow characteristics are related. In other words, a channel is a self-forming feature, and its size is determined by the amount of water and sediment it must carry. Thus, for the many small streams in the West which have no gaging record, channel size can be used to estimate the stream's flow regime. Several studies have correlated stream size with hydrologic data from gaging stations and have extrapolated this information to ungaged streams within areas of common hydrology and geology. Hedman and Osterkamp's (1982) summary of some of these studies is outlined in table A-2.

Two terms are used by geologists to describe physical channel characteristics: bankfull stage and active channel (fig. A-9). Bankfull stage is a term intimately related to the concept of the active flood plain because the active flood plain is formed as channels which

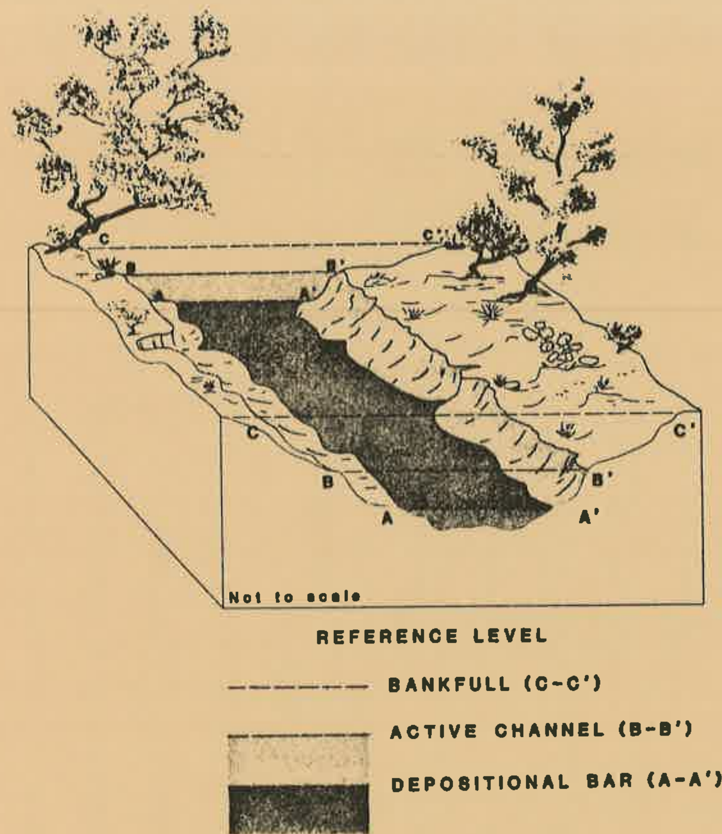

Fig. A-9. Commonly used reference levels for determining channel size.

TABLE A-2

EQUATIONS FOR DETERMINING MEAN ANNUAL RUNOFF FOR STREAMS IN WESTERN UNITED STATES

Flow Frequency	Areas of Similar Regional runoff characteristics	Percentage of time having discharge	Channel material characteristics[a]	Equation[b]	Standard error of estimate (percent)
Perennial	Alpine	More than 80	Silt-clay and armored	$Q_A = 64W_{AC}^{1.88}$	28
Intermittent	Plains north of latitude 39° N.	10 to 80	Silt-clay and armored	$Q_A = 40W_{AC}^{1.80}$	[c]50
			Sand	$Q_A = 40W_{AC}^{1.65}$	[c]50
	Plains south of latitude 39° N.	10 to 80	Silt-clay and armored	$Q_A = 20W_{AC}^{1.65}$	[c]50
			Sand	$Q_A = 20W_{AC}^{1.55}$	[c]50
Ephemeral	Northern and southern plains	6 to 9	Silt-clay and armored	$Q_A = 10W_{AC}^{1.55}$	(d)
			Sand	$Q_A = 10W_{AC}^{1.50}$	(d)
	and intermontaine areas	2 to 5	Silt-clay and armored	$Q_A = 4.0W_{AC}^{1.50}$	[c]40
			Sand	$Q_A = 4.0W_{AC}^{1.40}$	[c]40
	Deserts the Southwest	1 or less	Silt-clay and armored	$Q_A = 0.0W_{AC}^{1.75}$	[c]75
			Sand	$Q_A = 0.0W_{AC}^{1.40}$	[c]75

[a]Silt-clay channels--bed material d_{50} less than 0.1 millimeter or bed material d_{50} equal to or less than 5.0 millimeters and bank silt-clay content equal to or great than 70 percent.

Sand channels--bed material d_{50} = 0.1-5.0 millimeters and bank silt-clay content less than 70 percent.

Armored channels--bed material d_{50} greater than 5.0 millimeters.

[b]Active channel width, W_{AC}, in feet; discharge, Q_A, in acre-feet per year.

[c]Approximate--standard error of estimate of the basic regression equation.

[d]Standard error or estimate not determined; graphical analyses.migrate laterally across the valley flat (fig. A-6). Bankfull stage is commonly

defined as the point at which streamflow just begins to overflow its banks onto the flood plain. Because the flood plain is not always the most prominent portion of the valley flat, care must be taken not to identify bankfull stage on the basis of its association with a terrace.

Development of the idea of the active channel came after investigators, particularly in the West, realized that bankfull stage was sometimes difficult to recognize in the field and that a smaller channel size, or in-channel reference level, for discharge-channel geometry correlations might indicate recent, rather than historic, stream dynamics. The most common in-channel reference level used is the active channel, which is defined by Osterkamp and Hedman (1977) as

> "a short geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level. The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge."

Williams (1979) summarized some of the different criteria that investigators have used to identify channel size:

1. The topographic break in slope from a vertical bank to the flat flood plain.

2. The topographic break in slope from a vertical bank to a gentler slope.

3. The elevation of the lower limit of perennial vegetation (usually trees or shrubs).

4. The elevation of the upper limit of fine-grained stream-deposited debris.

5. The elevation of the "active flood plain".

6. The elevation at which the width/depth ratio of a measured cross-section is at a minimum.

Clearly, one field definition of bankfull stage has not been developed. In the same channel cross-section, different bankfull levels can be identified, depending on which definition or combination of definitions is used. The term "active channel" has also been used by some investigators when using some of the above criteria. Therefore, when using an existing report on bankfull stage or active channels, it is important to use the method specified in the report actually being used. Otherwise, regression equations used in these reports will be misapplied.

The most questionable use of bankfull and active channel interpretations is in ephemeral streams. Unfortunately, these streams are also the most common ones for which such interpretations would be helpful. Some important reasons for the hesitation in use of these data are

1. There are very limited data about ephemeral streams, and therefore, correlations with hydrologic data are subject to wide error.

2. The limited occurrence of flow in these channels may mean that there is no relationship between hydrology and channel characteristics--there may be no "average" discharge in these streams.

3. Several diagnostic features useful in identifying bankfull stage may not be present in some small channels owing to the limited occurrence of flow.

Investigations by Schmidt (unpublished data) in southeastern Montana showed that on small ephemeral streams, there is no apparent relationship between drainage basin characteristics and channel size. Investigations by Curry and Weber (1976) showed some relationship betweeen bankfull size and infrequent large precipitation events at small stream gaging sites in the same region. Such a finding may be of use elsewhere and may imply that channel size in small ephemeral streams may be more closely related to the recent precipitation and runoff history of a basin than to any "average" hydrologic feature of the stream.

Apley (1976) found that in small ephemeral streams of the Powder River Basin in Wyoming with drainage basins less than 2.5 square miles, streams usually do not experience flow more than 3 to 5 days a year. It is not surprising that in these size streams, there may not be a flood plain or an active channel. These stream valleys may, however, have a larger feature, which NERCO (1981) termed the valley trench. Although this larger feature is clearly unrelated to the modern hydrologic regime, it may be a feature worth preserving in reclamation since it is a common feature of many streams (fig. E-3).

Osterkamp and Hedman (1982) collected channel geometry, channel sediment and discharge data for 252 perennial stream gaging stations in the Missouri River basin. Results of their data analysis show that channel width is the best variable to use in regression equations to determine discharge. Further improvement in the equations results from inclusion of channel sediment properties and channel gradient. The authors suggest that the equations developed are applicable outside the Missouri River basin.

Other studies which relate channel geometry to hydrologic characteristics done in individual States are listed on page B-21 in appendix B.

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APPENDIX B

SURFACE IRRIGATION PRACTICES IN THE WEST

Introduction

Surface irrigation plays a vital part in sustaining the agricultural economy of all Western States. Water distribution is accomplished on irrigated lands by means ranging from uncontrolled flooding to highly engineered and elaborately equipped automated systems. Surface water has been the primary source of irrigation in all the Western coal regions, but, within each region, irrigation practices vary with the different environmental conditions. Factors affecting irrigation use patterns include water availability and quality, the degree of Government subsidy, distribution of water rights, and the different management decisions of individual farmers and ranchers.

Flood irrigation methods have traditionally been considered the most economical use of surface water primarily because the initial capital investment of these systems is generally the lowest. The low initial investment is frequently accompanied, however, by a high labor requirement during the irrigation season. Most lands naturally adapted to flood irrigation can receive water from gravity flow sources or require pumping only to the extent of lifting water to the highest point in the field. Natural limitations to effective irrigation by surface methods are steep slopes and soils with very

high intake rates (permeability). Inefficiencies generally attributed to surface irrigation systems include water losses from the primary and secondary distribution layouts and unnecessary water losses caused by a lack of understanding of the intake rate and water-holding capacity of the soil being watered.

The remainder of this appendix explains the various methods of surface irrigation found in the West, discusses the factors to be considered in choosing a system, and outlines the typical irrigation practices of each coal region.

Types of Application Methods

The different styles of irrigation practices are important to observe when conducting regional agricultural use surveys and assessing the capability of undeveloped lands to be irrigated. Styles of irrigation not characteristic of a region should not be considered potential methods for purposes of alluvial valley floor studies.

Surface irrigation methods can be classified as either flood, drip, or sprinkler methods. Flood irrigation is practiced by flooding the surface with water. Sprinkler irrigation involves spraying water into the air above the ground. Drip irrigation provides a continuous water supply from pipes. More detailed information on these methods can be found in irrigation guides published for each Western State by the Soil Conservation Service or in standard irrigation textbooks (Hanson and others, 1980, Hagan and others, 1967).

A. Sprinkler irrigation is conducted with many different types of equipment and methods. In general, water is sprayed into the air and allowed to fall on the land surface in a uniform pattern at a rate approximately equal to, or less than, the infiltration rate of the soil. This method simulates rainfall, and efficiencies of 65 to 75 percent can be achieved. Water losses using this method are due to evaporation of the sprinkler spray, evaporation from wetted leaves, nonuniform distribution caused by sprinkler pattern, and wind. Common sprinkler systems are lateral pipes moved by hand or mounted on wheels, single high-capacity nozzles which rotate, and center-pivot irrigation systems. Sprinkler irrigation is adaptable for a very wide variety of crops and soils. The water supply for many sprinkler irrigation systems in the West is either pumped from ground water or is supplied through large-scale irrigation diversion systems. Because both of these water sources can supply water to agricultural land located away from stream valleys, sprinkler irrigation is the most common irrigation method on upland areas. However, some farms and ranches have converted traditional flood irrigation systems to sprinklers on valley bottom fields to reduce labor costs. In most of these cases, surface water is still the source of irrigation.

B. Drip irrigation is the frequent and slow application of water to soil through mechancial outlets. The objective is to continuously supply each plant with enough moisture to meet evapotranspiration needs. Water wastage is reduced considerably.

Drip irrigation is used where water is expensive and crops provide high monetary return on small acreage. Orchards are a typical crop irrigated by this method. Drawbacks to this technique are initial capital costs and high maintenance requirements.

C. Flood irrigation methods can be broken down into two broad classifications--flooding and furrow. All modifications of the flooding method involve covering the entire field surface with water for a period of time and letting it percolate downward into the soil profile. Furrow irrigation wets only a part of the soil surface and results in less loss to direct evaporation than full flooding methods. Movement of water into the soil using the furrow method is both lateral and downward. Different types of flood irrigation methods are described below.

1. Border irrigation is a controlled surface flooding method of water application. The irrigated field is divided into strips, usually 20 to 60 feet wide, separated by parallel dikes or "border ridges." Each strip is irrigated separately. Water is introduced at one end and progressively covers the entire strip. Border irrigation is practiced on either level or graded fields.

a. Level border irrigation applies water by ponding. Each strip of the field in this case has no slope and is enclosed by border ridges. All water applied is retained and absorbed

into the soil. This type of irrigation is best suited to soils that have moderate to extremely low intake rates. Advantages of level border irrigation are that many different kinds of crops can be grown in sequence without making major changes in design, layout, or operating procedures. High application efficiency can be obtained easily. The method is well suited to mechanization, can be adapted easily to automation, and can be operated efficiently by inexperienced workers. There are almost no crops that cannot be grown with level border irrigation. It is widely used for close-growing crops, such as alfalfa and other legumes, grasses, and small grains.

b. In graded border irrigation water is applied at the uphill end of each strip and is absorbed into the soil as it flows down the sloped field. The stream of water is such that the desired volume of water is applied at the upper end of the strip in a time equal to or slightly less than that needed for the soil to absorb the net amount required. The stream is turned off after application of the desired volume of water. The water temporarily stored on the ground surface then flows down the strip and completes the irrigation. Uniform and efficient water application is dependent upon use of irrigation streams of the proper size. Field application efficiencies of 60 to 75 percent usually are possible if systems are properly designed and managed. Labor requirements are low, and border strip dimensions can be designed for efficient operation of farm machinery. Fields best suited for this type of irrigation have a slope of 0.1 to

2.0 percent with zero cross-slope. The maximum length of run depends on the soil and stream size but is normally limited to 1,300 feet. Border strips generally require relatively large stream sizes, uniform soil, and uniform land slopes. The graded border method of water applicaion is suitable for close-growing, noncultivated, sown or drilled crops. Legumes, grasses, and small grains are commonly irrigated by this method.

2. Furrow and corrugation irrigation involves directing streams of water into furrows or corrugations graded with a shallow slope in a field. Water is usually pumped or siphoned from an irrigation ditch or other water source. There will be surface runoff, and drain ditches are necessary to carry water off the lower end of the field. This water can be returned to a head ditch, to another field, or to the source. Furrow irrigation is used for row crops, such as corn and sugar beets, whereas corrugation irrigation is used for close-growing crops, including pasture grass, alfalfa, and small grains. Either irrigation system requires relatively little capital investment and complements other cultural practices, such as cultivating. The method works well with stream diversions because high pressures are not required, and large or small flows can be utilized by varying the number of furrows watered at one time. Skilled labor is required for operation and annual touch-up grading is necessary.

3. Contour ditch irrigation generally consists of a series of ditches on a suitable grade following the general contour of the land (figs. B-1, B-2). These ditches are usually designed with spacing of 200 to 500 feet between ditches on fields with slopes of up to 6 percent. The fields in between are then irrigated by controlled flooding. Runoff water usually collects in the next ditch downslope and is used to supplement the water subsequently applied to irrigate the next elevation. The contour ditches either have many openings or canvas or plastic check dams are periodically moved to permit water to flow from the ditch to adequately maintain waterspread for the entire breadth of the field. Land smoothing will improve the water distribution. Field application efficiencies should be between 40 and 60 percent for properly designed and operated systems which reuse tailwater on successive closely spaced contour ditch areas.

4. Field flooding irrigation is the oldest form of irrigation water distribution (fig. B-3) and is used when an abundance of water is available, and the crops grown are principally hay and pasture. It is a common but usually wasteful practice. Irrigation ditches are generally located without much planning, and few are used. This method may be as elementary as diverting the flow of a stream or ditch to a field area and letting the water run wild. One man can handle large amounts of water and irrigate large acreages under favorable conditions where the land is comparatively level and

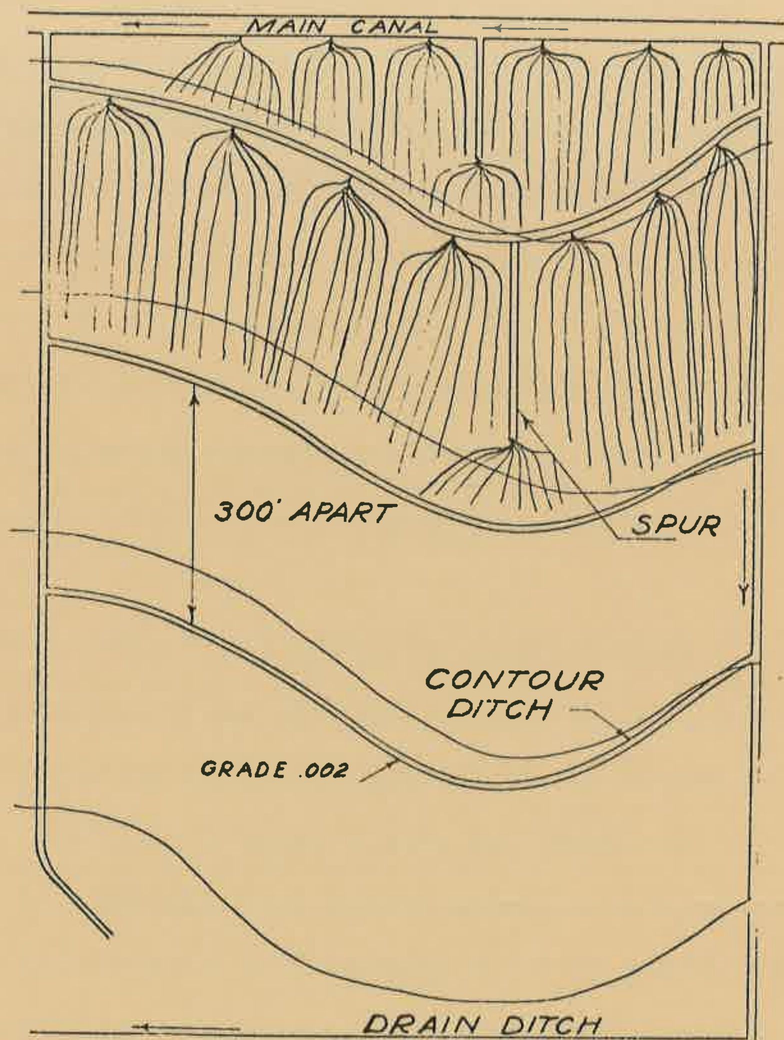


Fig. B-1 Typical contour ditch system for irrigating steep irregular fields. (Dusenberry, 1950.)

Fig. B-2 Contour ditches in alfalfa field along Prairie Dog Creek near Sheridan, Wyoming.

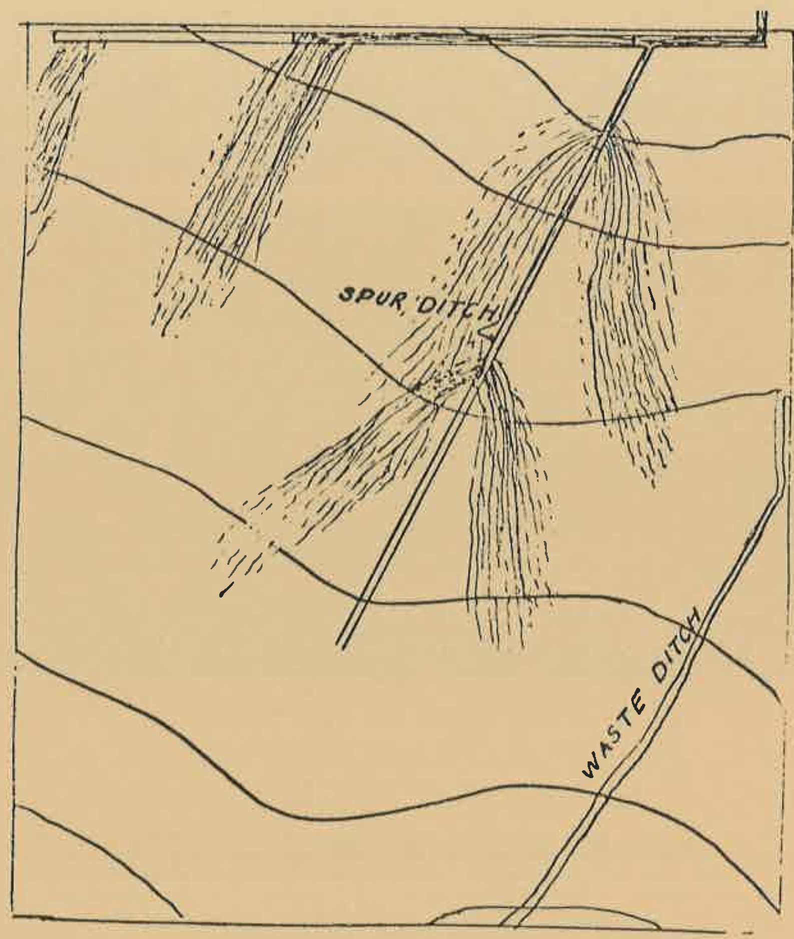


Fig. B-3 Wild flooding method of irrigation. Note scarcity of ditches. (Dusenberry, 1950.)

easily flooded. This method often gives poor control of water and results in high runoff and, frequently, waterlogging of certain areas.

Surface flooding by use of spreader dikes is commonly practiced on low-lying terraces in drainage basins of relatively small size (less than 50-100 square miles). An earthen dam is built across the stream and part of the terrace to be flooded (fig. B-4). A series of dams is sometimes built along a reach of stream. Floodflows caused by annual snowmelt or large rainfall events are ponded by the dams and forced to spread out over the terrace. Dikes built in the field retain water on the field and then direct it to other parts of the field. When used on larger streams, a culvert is placed in the dam to allow low-flow drainage, but the earthen berms are still occasionally washed out by large floods. Spreader dikes are most common on ephemeral drainages in which more extensive irrigation structures are not feasible due to the unpredictability of the size and timing of floodflow and the very short duration of the floodflow.

D. Artificial subirrigation is not a surface irrigation method but is mentioned here for the sake of completeness. It is used in a few localities where natural soil and topographic conditions are favorable to the applicaion of water to soils directly under the surface. A permeable loam or sandy loam surface soil, a very permeable subsoil, an impervious layer below the subsoil 6 feet or more below

Fig. B-4 Spreader dike across Dry Creek, tributary to the Powder River, near Interstate 90, Johnson County, Wyoming. The valley bottom has aggraded somewhat in response to spreader dikes on this drainage.

the surface, uniform topographic conditions, and moderate slopes favor artificial subirrigation.

Considerations in Choosing and Developing an Irrigation System

This discussion outlines considerations in developing irrigation systems, and its application in alluvial valley floor studies is in developing detailed studies of irrigation capability. As explained in chapter II, regional evaluations will lead to an apparent pattern of irrigation development. If an applicant questions this pattern, detailed studies might be undertaken in order to show why irrigation is not feasible in a particular valley. Thus, site data may be used to show that specific factors used in designing irrigation systems could preclude, within the valley in question, the kind of development characteristic of the region.

The factors which are considered in choosing or changing irrigation systems include the soil type, topography, water supply, water quality, climate, crops, labor supply, economic feasibility, and finances. Many of these parameters are interrelated and consideration of all of them can reach such complex levels that decisionmaking approaches intuition. Thus, for any specific situation, different individuals may well make different choices about the best irrigation system or even about whether irrigation is feasible.

A. Soil. The type of soil is a major factor in choosing an appropriate irrigation system and in planning the system. Soil serves as a reservoir for water and nutrients and gives physical support to plants. The rate at which water can infiltrate the soil and the storage capacity of the soil are fundamental characteristics, and the irrigation system must match these characteristics (table B-1). Generally, soils with very high intake rates are not suited to surface irrigation methods, and soils with very low intake rates normally should not be sprinkled. To make any irrigation system practical, the soil must be capable of storing moisture between water applications, and the soil must be deep enough for adequate root development.

Topography is of prime importance in determining the feasibility and correct method of irrigation. Some methods require level fields (e.g., level border irrigation), others are designed for specific slopes (e.g., furrow irrigation), and some, such as sprinkler irrigation, work on flat or undulating fields (table B-2). Land leveling is required for some irrigation systems to ensure proper distribution of water. Most methods have greater efficiency when fields are leveled because the water is more evenly distributed over the entire field. Erosion is a potential hazard when irrigating, especially on sloped fields, and soil structure can be damaged by flowing water. Therefore, topography which concentrates surface flows should be avoided or eliminated by grading.

TABLE B-1

WATER-HOLDING CAPACITIES OF SOILS

Soil texture	Range of available moisture (inches per foot)
Sands and fine sands	0.5 - 1.0
Very fine sands, loamy sand, and loamy fine sand	0.7 - 1.4
Sandy loam and fine sandy loam	1.2 - 1.7
Loam and very fine sandy loams	1.7 - 2.2
Silty loams and silts	1.9 - 2.4
Clay loams, sandy clay loams	1.4 - 1.9
Silty clay loams	1.7 - 2.2
Clay and silty clay	1.3 - 1.8
Heavy clays	1.2 - 1.7

Source: Colorado Irrigation Guide (SCS, undated).

TABLE B-2

SLOPE LIMITATIONS FOR IRRIGATION METHODS

	Design slope (percent)							
Method	Level	0.1	0.2	0.4	0.75	1.5	3.0	6.0
Level border	X	--	--	--	--	--	--	--
Graded border	--	X	X	X	X	X	X[1]	--
Furrow	--	X	X	X	X	X	--	--
Contour ditch	--	--	--	--	X	X	X[1]	X[2]
Sprinkler	X	X	X	X	X	X	X	X[2]
Maximum nonerosive furrow stream (gpm)	--	50	50	25	13	7	--	--

[1]Sod crops only.

[2]Srinkler adaptable to slopes to 15 percent. Slopes greater than 8 percent require stable soils and sod crops.

Source: Colorado Irrigation Guide (SCS, undated).

County soil surveys by the Soil Conservation Service provide good information about the general nature of different combinations of soils and topography and their suitability for irrigation. Information provided in a soil survey of a specific area provides a starting point; however, a more detailed field assessment is useful. Soil surveys have data on the depth, drainage characteristics, water capacity, and slope of all soils mapped and also provide an indication of the suitability of each soil for irrigation diversions.

B. Water Quantity. Irrigation systems are typically designed to provide sufficient water to meet crop needs during the growing season, particularly during periods of peak consumptive water use by crops. In drainages which have a limited runoff season and in which storage is not practicable, surface irrigation can still produce a beneficial increase in production. Table B-3 indicates critical growth periods for various crops and table B-4 indicates crop adaptations for the various irrigation methods. Water requirements of crops for various climatic conditions are usually determined from estimates of potential evapotranspiration made from equations, such as the Blaney-Criddle formula, or from field experiments. Water requirement for specific crops is listed in irrigation guides for each State published by the Soil Conservation Service and in other references, such as Jensen and others (1974), Doorenbos and Pruitt (1974), and SCS (1970).

TABLE B-3

CRITICAL GROWTH PERIODS FOR MAJOR CROPS

Crop	Indications of moisture stress	Critical growth period	Other considerations
Alfalfa	Darkening color, then wilting.	Early spring and immediately after cuttings.	Normally 3-4 inches of water are needed between cuttings. Fall irrigation is desirable.
Corn	Curling of leaves by midmorning.	Tasseling, silk stage until grain is fully formed.	Needs adequate moisture from germination to dent stage for maximum production.
Sorghum	Curling of leaves by midmorning.	Boot, bloom, and dough stages.	Yields are reduced if water is short during seed development.
Sugar beets	Leaves wilting during heat of day.	Post thinning.	Excessive fall irrigation lowers sugar content.
Beans	Wilting.	Bloom and fruit set.	Yields are reduced if water is short at bloom or fruit set.
Small grains	Dull green color, then firing of lower leaves.	Boot and bloom stage.	Last irrigation at milk stage.
Potatoes	Wilting during heat of day.	Tuber formation to harvest.	Moisture stress during critical period may cause cracking of tubers.
Onions	Wilting.	Bulb formation.	Keep wet during bulb formation, let soil dry near harvest.
Tomatoes	Wilting	After fruit set.	Wilt and leaf rolling can be caused by disease.
Cool season grass	Dull green color, then wilting.	Early spring, early fall.	For seed production, critical period is boot to head formation.
Fruit trees	Dulling of leaf color color, and drooping of growing points.	Any point during growing season.	Stone fruits are sensitive to moisture stress during last 2 weeks prior to harvest.

Source: Colorado Irrigation Guide (SCS, undated).

TABLE B-4

CROP ADAPTATIONS TO IRRIGATION METHODS

Crop	Water extraction depth (ft)	Furrow spacing (in.)	Maximum furrow capacity (gpm)	Adapted Irrigation Methods				
				Level border	Graded border	Contour ditch	Furrow	Sprinkler
Alfalfa	5	---	---	X	X	X	---	X
Beans (dry)	3	22	25	---	---	---	X	X
Beets (sugar)	4	22	25	---	---	---	X	X
Corn (silage)	4	36	50	X	X	---	X	X
Corn (sweet)	3	36	50	X	X	---	X	X
Grain (spring)	4	---	---	X	X	X	---	X
Grain (winter)	4	---	---	X	X	X	---	X
Grass	3	---	---	X	X	X	---	X
Orchards	5	---	---	X	X	---	---	X
Peas	3	22	25	---	---	---	X	X
Potatoes	2	36	50	---	---	---	X	X
Sunflowers	3	36	50	---	---	---	X	X

Source: Colorado Irrigation Guide (SCS, undated).

Determining the actual amount of surface water available for irrigation use in a drainage in many cases is not necessary because all the water has been appropriated. A prospective irrigator commonly either owns the water rights to a certain amount of water or must attempt to acquire rights to the water needed. If the surface flows are not totally appropriated or used, the amount of water available can be estimated from gaging records or by various other means. Some perennial streams are gaged by the U.S. Geological Survey and records of average daily discharge are available for as many as 30 or more years for some streams. However, in the semiarid West, there are few perennial streams. These few large perennial streams provide the main component of surface irrigation water in stream valleys in the West.

For small perennial streams and ephemeral and intermittent streams, long-term gaging records generally are not available. Estimates of discharge must then be made by various methods of regional analysis. These methods utilize available gaging records for streams in an area and extrapolate estimates to ungaged streams on the basis of similarity with other physical factors (drainage basin characteristics and channel characteristics, for example). Most of these techniques give estimates of magnitude and frequency of floods, low flows, and mean annual discharge. Although these techniques do not give average daily or monthly streamflows during the irrigation season, comparison with gaging records of nearby streams can at least permit estimates of monthly flows.

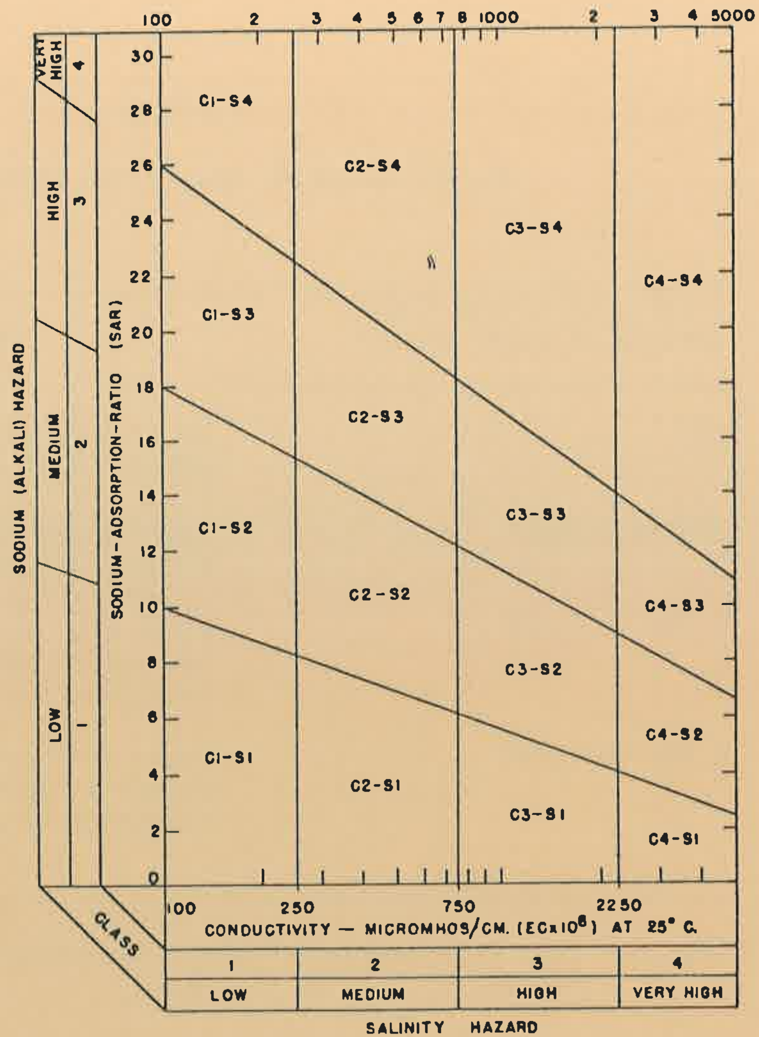
Riggs (1973) provided a good overview to the topic of regionalization of streamflow data, and Hedman and Osterkamp (1982) reviewed empirical equations developed for Western stream channels to estimate streamflows from channel geometry. Estimation methods which relate mean annual discharge and magnitude and frequency of floods with drainage basin characteristics and stream channel geometry have been completed by the USGS in the following Western States: North Dakota (Crosby, 1975); Montana (Parrett and Omang, 1981); Wyoming (Craig and Rankl, 1978; Hedman and Kastner, 1977; Lowham, 1976); Colorado (Hedman and others, 1972; McCain and Jarrett, 1976); New Mexico (Borland, 1970; Kunkler and Scott, 1976; Thomas and Dunne, 1981); and Utah (Eychaner, 1976; Fields, 1975). Estimation of flows from channel characteristics is discussed further in appendix A.

C. Water Quality. Water of suitable quality is important for proper irrigation. Plants can extract more water from a salt-free soil than from the same soil with high salt content. All water contains some dissolved salts or minerals. Without leaching, salts accumulate in the soil as the water is drawn off through evapotranspiration. A favorable salt balance is reqired for successful irrigation over the long term. The output of salts in water draining through the soil must exceed the input of salts in the irrigation water. Where soils do not drain well or where high water tables exist, the removal of salts is impeded, and soils can become saline.

Salinity can affect plants in many ways physiologically. However, overt injury symptoms, such as leaf necrosis, seldom occur except under extreme saline conditions. Plants affected by salinity usually appear normal but have decreased rates of water absorption and, hence, reductions in yields. As salt concentration increases above a threshold level for a given plant species, both the growth rate and the ultimate size of most plant species will progressively decrease. Top growth is often affected more than root growth (Maas and Hoffman, 1977). In addition to reductions in yields, plants grown under high salt conditions often have reductions in the quality of yield as well. For areas where salinity is a problem, crops which produce satisfactorily under existing saline conditions can be selected. In selecting such crops, it is important to be aware that certain crops are more sensitive to saline conditions during germination and much more tolerant during later stages of growth. Field crops with good salt tolerance include barley, sugar beets, alfalfa, and sweetclover (SCS, 1977).

The suitability of water for irrigation depends on the amount and composition of the solids dissolved in it. Salinity (as measured by total dissolved solids) and sodium are the two most commonly used indicators for irrigation water classification (fig. B-5). Table B-5 suggests criteria for classifying the TDS hazard of waters in arid and semiarid regions, and table B-6 presents similar criteria developed by McKee and Wolf (1974) on the basis of an extensive survey of the

Fig. B-5. SAR--Conductivity classification of irrigation water. Source: U.S. Salinity Lab (1954).



CONDUCTIVITY

C1 Low-salinity water: Can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop.

C2 Medium-salinity water: Can be used if a moderate amount of leaching occurs.

C3 High-salinity water: Cannot be used on soils with restricted drainage. With adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

C4 Very high salinity water: Is not suitable for irrigation under ordinary conditions.

SODIUM

S1 Low-sodium water: Can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

S2 Medium-sodium water: Will present an appreciable sodium hazard in fine-textured soils having a high cation-exchange capacity, especially under low-leaching conditions.

S3 High-sodium water: May produce harmful levels of exchangeable sodium in most soils and will require special soil management — good drainage, high leaching, and organic matter additions.

S4 Very high sodium water: Is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity.

TABLE B-5

DISSOLVED-SOLIDS HAZARD FOR IRRIGATION WATER

Total dissolved-solids content of water (mg/L)	Remarks
500	Water from which no detrimental effects will usually be noticed.
500 to 1,000	Water which can have detrimental effects on sensitive crops.
1,000 to 2,000	Water that may have adverse effects on many crops and requires careful management practices.
2,000 to 5,000	Water that can be used for tolerant plants on permeable soils with careful management practices.

Source: U.S. Environmental Protection Agency, (1976); National Academy of Science (1973).

TABLE B-6

SUMMARY CLASSIFICATION OF IRRIGATION WATERS

	Water class[1]		
	I	II	III
Boron (mg/L)	Less than 1.0	Less than 2.0	Less than 3.0
SAR	Less than 1.0 to 4.2[2]	1.0 to 11.6	Greater than 9.0 to 11.6
Chlorine (meq/L)[3]	Less than 2.0 to 5.5	2.0 to 16.0	Greater than 6.0 to 16.0
Sulfate (meq/L)	Less than 4.0 to 10.0	4.0 to 20.0	Greater than 12.0 to 30.0
Specific conductance	Less than 500 to 1,000[4]	500 to 3,000	Greater than 2,500 to 3,000
TDS (mg/L)	Less than 700	350 to 2,100	Greater than 2,500 to 3,000
Salinity hazard	Low to medium	Medium to very high	Very high

[1]The water classes are defined for two purposes: first, in relation to overall soil/climate management, as:

I (excellent to good; suitable under most conditions).
II (good to injurious; harmful under certain conditions of soil, climate, and practices).
III (injurious to unsatisfactory; unsuitable under most conditions).

and, second, in relation to plants, as:

I (suitable for irrigation of all or most plants, including salinity- and boron-sensitive species).
II (not suitable for most salinity- and boron-sensitive plants; suitable for all tolerant and many semitolerant species).
III (unsatisfactory for most plants except those that have a high tolerance for saline conditions and high boron levels).

[2]Recent work favors the upper limit.
[3]meq = milliequivalents.
[4]In µmhos/cm at 25°C.

Source: Mckee and Wolf (1974).

literature. Other studies have determined the tolerance of individual plant species to water of different qualities (Gough and others, 1979; Christiansen and others, 1977; Ayers, 1977; Maas and Hoffman, 1977). Ultimately, the suitability of water for irrigation depends on the type of crop, the type of soil, and acceptable yield reduction. In some localities high-salinity- or high-sodium-hazard water from streams or wells is used for irrigation, usually because of the lack of better water. Soils in these fields can be adversely affected or accumulations of salts can be leached by excessive irrigation. Application of any water quality criteria must be tempered with the knowledge that the criteria may have been developed in regions with different climatic conditions and that site-specific conditions may make any individual criterion too stringent or lenient.

D. Climate determines the need for water, the crops grown, and influences the choice of irrigation method. Total annual precipitation and its seasonal distribution are the most important climatic characteristics relating to the need for irrigation. Temperature, wind, and hours of sunshine also affect plant growth and irrigation requirements.

E. Crops. The crop(s) to be irrigated in one field is an important parameter in choosing an irrigation system (table B-4). Different crops need different amounts of water. The amounts of water

needed vary with the length of the growing season and the portion of the plant which is harvested. Rooting depth controls the frequency and amount of irrigation applications.

F. Labor availability and costs are becoming increasingly important in choosing an irrigation method. All methods can be automated, but sprinklers adapt most readily. If an abundance of cheap labor is available, or if irrigation can be interspersed between other farm chores, surface irrigation may be best. Initial low-capital investments generally buy systems requiring the most labor. A greater capital investment and less labor is required when more costly methods are chosen.

Methods of Obtaining Surface Water

Various methods are used to obtain surface water for surface irrigation systems. Diversion systems used on ephemeral or smaller perennial streams are developed where construction of reservoirs is not suitable (fig. B-6). Streamflows are diverted by earthen, metal, or concrete dams built across the channel into ditches which convey water to irrigated fields, which may be several miles from the diversion point. On larger perennial streams, it is usually more practical to build an impoundment because suitable damsites may be available and economies of scale allow for lower unit cost for water delivered from larger systems. Impoundment and ditch systems utilize water storage behind a dam to supply water to fields through sometimes

Fig. B-6 Metal diversion dam on Prairie Dog Creek near Sheridan, Wyoming. Headgate for the diversion ditch is located on the far side of the stream.

very extensive ditch systems throughout the growing season. In some instances, water is pumped from a stream to a ditch because the pump system is cheaper than constructing and maintaining a long ditch, which would be required for a gravity flow sytem (fig. B-7). Spreader dikes, as mentioned under irrigation methods, impound water temporarily until flow can spill out of the channel and flow overland across fields on low-lying terraces.

Summary of Regional Practices

Surface irrigation practices in each of the coal regions of the West vary due to differences in climate and demand for various crops. The irrigation methods described in this paper can be used in any region; however, specific methods are more predominant in certain regions due to various environmental factors. After OSM completes a study of regional irrigation practices in Western coal regions (early 1984), more complete summaries of regional irrigation practices can be developed. The following briefly summarizes regional practices and available irrigation data. It is strongly recommended that any published irrigation survey be field checked because discrepancies may exist due to the age of survey, variable mapping units, and the degree of care taken by the particular mappers.

A. Fort Union Coal Region. Alfalfa and grass hay are the major irrigated crops grown on valley floors in the Fort Union coal region (fig. B-8); however, other crops, particularly sugar beets, are

Fig. B-7 Irrigation water is supplied to contour ditches (beyond telephone poles) by pumping from Dutch Creek near Sheridan, Wyoming. Pump (foreground) has been pulled from stream and pipeline moved, both readied for winter storage.

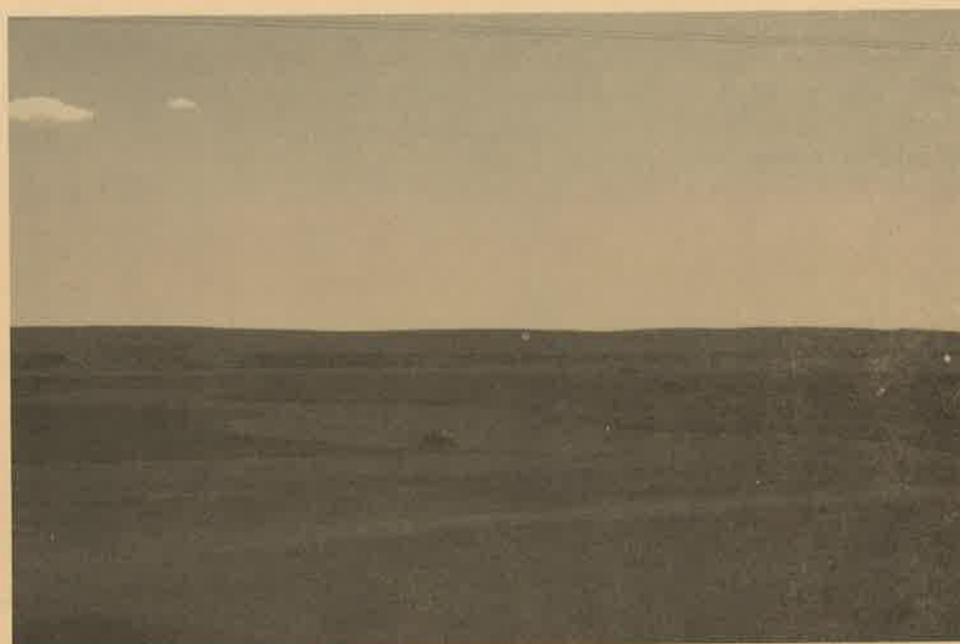


Fig. B-8 Flood-irrigated alfalfa fields along the Redwater River, Dawson County, Montana.

irrigated along the Yellowstone River of Montana and the Missouri River of North Dakota. Irrigated acreage has been mapped in east-central Montana by Schmidt (1977), in southeastern Montana by Druse and others (1981), in Carter County, Montana, by Yellowstone-Tongue A.P.O. (1977a), and in all counties of Montana by the Department of Natural Resources in published water resource surveys and published and unpublished land classification maps. The State of North Dakota has identified irrigated areas of Dunn County.

B. Powder River Basin Coal Region. Diversion ditches, reservoir-ditch systems, and spreader dikes are the three most popular methods of surface irrigation on valley floors of the Powder River Basin coal region in Montana and Wyoming. The predominant irrigated crop is alfalfa and grass hay, although other crops (corn, sunflowers) are grown along the major rivers.

Spreader dikes are used on ephemeral and intermittent streams in the upper parts of drainage basins where flood runoff is not large enough to wash out the dikes (fig. B-4). Spreader dikes are most frequently used on ranches not owning irrigated hayland along perennial streams. The inconsistent development of irrigated hay meadows on some major streams may be due to land ownership patterns, lack of water rights, or poor water quality in some perennial streams. The diversity of irrigation paractices is illustrated in the following examples:

1. In the Powder River drainage in Montana, the ranches tend to be small and those without land along the Powder River have developed spreader dike systems on smaller streams.

2. Along Crazy Woman Creek in Johnson County, Wyoming, very few ranches have water rights for the stream and, instead, use spreader dikes to divert flow from tributary ephemeral tributaries into the larger terraces of Crazy Woman Creek (fig. B-9).

3. The suspended sediment load of the Powder River in Johnson County, Wyoming, is so high that the water is not suitable for flood irrigation, even though the valley is large (fig. A-3). Therefore, ranches in this area use spreader dikes both along tributaries and on Powder River terraces, where the tributaries join the river.

Intermittent and small perennial streams frequently are diverted into ditches several miles long. These ditches typically feed contour ditch or wild-flooding irrigation systems on fields on valley floors. Such systems are developed, for example, along Squirrel Creek near Decker, Montana, and along Wild Horse and Spotted Horse Creeks in northwestern Campbell County, Wyoming. Flow is diverted during spring runoff and may continue into late spring or summer if there is sufficent flow. Major rivers, such as the Tongue River, Prairie Dog Creek (fig. B-2), and Clear Creek, have storage reservoirs which release water to the river during the irrigation season. Water is either diverted to ditches or pumped to ditches which lead to irrigated fields. Some sprinkler irrigation is practiced by pumping from the river or ditch.

Irrigated acreage in the Powder River Basin has been mapped by Druse and others (1981), in southeastern Montana by Yellowstone-Tongue

Fig. B-9 Dikes on terraces of Crazy Woman Creek, Johnson County, Wyoming, spread water from tributaries. This rancher does not have water rights on Crazy Woman Creek, a perennial stream.

A.P.O. (1977b), and in Wyoming by the Wyoming State Engineer's Office (1971). Inventories by the Montana Department of Natural Resources are available for all Montana counties.

C. Green River-Hams Fork Coal Region. Irrigated valley floors in this area of Wyoming and Colorado are primarily used for hay production. At higher elevations on streams draining mountains, spring snowmelt is diverted to flood irrigate native grasses, alfalfa, or other hay grass grown on mountain meadows. In high-elevation areas with many perennial streams, such as the Upper Yampa River basin, ditch development can be extensive. Natural subirrigation is usually a supplemental source of water later in the growing season. Larger impoundment/ditch and diversion structures are used on the lower lying major rivers.

D. Unita Coal Region. Two major irrigation methods are used in the Uinta coal region in Colorado and Utah. Mountain meadows typically produce hay irrigated by diversion of spring snowmelt floodflows. Along large rivers having broad valleys, such as the Gunnison, Green, and White Rivers, large irrigation diversion systems supply water for irrigation of many diverse crops. Crops irrigated include hay, small grains, row crops, and orchards. Irrigated land has been mapped in some Colorado counties by the SCS (1980). Along the Book Cliffs and Wasatch front of Utah, virtually every perennial stream has been diverted to irrigated crops in the Grand and Castle valleys.

E. San Juan Coal Region. The only irrigated farmland in valley bottoms in the San Juan coal region occurs along the larger perennial streams that head in alpine areas. These rivers have sustained flow through the growing season and are easily diverted with large-scale systems. In smaller drainages, sizeable floodflows occur but are not easily diverted because of their size and infrequency. Some streams may have been diverted decades ago but cannot be now, owing to recent incision of the stream channels. Diversions and irrigated land in New Mexico has been mapped by Cornelius and others (1978) and by Love and others (1981).

F. Southern Utah. Schmidt (1980) identified the major surface irrigation practice in southern Utah to be diversion of streams heading on high plateaus (fig. B-10). Hay is the dominant irrigated crop.

Fig. B-10 Flood-irrigated and flood-irrigable area on Johnson Wash, Kane County, Utah. Designated alluvial valley floor.

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APPENDIX C

SUBIRRIGATION AND ITS ASSESSMENT

Introduction

The identification of subirrigated areas (fig. C-1) is important in identifying alluvial valley floors, since alluvial valley floors include areas where water is "sufficient for subirrigation * * * agricultural activities." This appendix is intended to provide the user with an understanding of what subirrigation is, how it can be identified, how it can be mapped, and what references are available on the topic.

General Definitions

Subirrigation, in terms of the alluvial valley floor regulatory program, is "the supplying of water to plants from underneath or from a semi-saturated or saturated zone where water is available for use by vegetation" (30 CFR 701.5). The U.S. Soil Conservation Service (SCS) definition of a naturally subirrigated area is land "with an effective subsurface ground-water table and water rarely over the surface during the growing season" (Zacek and others, undated). Implicit in the SCS definition is that ground water is useable for the entire growing season, or a sizeable portion of it.

When considering subirrigation, biologists are more inclined to consider the plants and plant communities growing in a particular area

Fig. C-1 North Fork Burns Creek, Dawson County, Montana. Narrow, lower terrace is subirrigated. Broad, upper terrace may have the capability to be flood irrigated.

than the physical attributes of the substrate. Several terms commonly used by vegetation specialists to characterize plants which grow in the presence of ground water are phreatophyte, riparian vegetation, and hydrophyte. Phreatophytes are plants that depend upon ground water for their water supply (Robinson, 1958). Examples of phreatophytes are alfalfa, saltcedar, cottonwood, and giant wildrye. Hydrophytes are plants which grow in water or depend upon being partially immersed in water at all times (Billings, 1970). Examples include water lilies and cattails. Riparian vegetation is a term for a plant community inhabiting the banks and adjacent areas of lakes, streams, and springs (Warner, 1979). Riparian vegetation is dependent on surface or ground water transported to the site to provide the extra soil moisture not available in other areas. A riparian community is composed of phreatophytes and upland plants and, thus, includes species such as Western wheatgrass or silver sage, which can utilize available ground water but will also grow on upland sites.

Robinson (1958) compiled a list of phreatophytes which occur in the West. Most of these species, however, are not valuable either as range or cultivated plants, but they are important as indicators of subirrigated sites. Their presence, in conjunction with other observations, can be used to assist in defining the extent of an alluvial valley floor. Table C-1 presents a list of phreatophytes known to occur in coal regions of the West. Those with economic value as livestock forage are noted.

TABLE C-1

SOME PHREATOPHYTES OF THE COAL REGIONS OF WESTERN UNITED STATES

(Data from Robinson (1958) unless otherwise noted)

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality[1]	Remarks (*Indicates species is agriculturally useful)
Acacia greggii A. Gray	Catclaw, devilsclaw, una de gato	Southern California to western Texas	--	1	Uses more water than mesquite (McGinnies and Arnold, 1939, p 236). Forms thickets along streams and washes.
Acer negundo Linnaeus	Boxelder	Canada to Oklahoma	--	--	Occurs in moist places and along streams, chiefly in mountains. Also common in riparian zone of prairie streams (Daubenmire, 1978).
Allenrolfea accidentalis (S. Watson) Kuntze	Pickleweed, Iodinebush	California to western Texas	1-20	3	Found on moist saline areas.
Anemopsis californica (Nuttall) Hooker and Arnott	Yerba mansa	Southern California, southern Nevada to Utah and Texas	Shallow	3	Common in saline and wet lowlands.
Artemisia cana Pursh	Silver sagebrush	Montana to New Mexico	12+	2	Normally associated with lowland areas but on occasion can be found also on upland sites. Often associated with greasewood.
Atriplex canescens (Pursh) Nuttall	Fourwing, saltbush, chamiso, chamiza	South Dakota to Oregon, south to Mexico	8-62[2]	1-2	Tolerates alkali. Valuable browse plant. Useful in erosion control. Taproots 30-40 ft. deep (Van Dersal, 1938, p. 65). May not always occur as a phreatophyte.

TABLE C-1

SOME PHREATOPHYTES OF THE COAL REGIONS OF WESTERN UNITED STATES (Continued)

(Data from Robinson (1958) unless otherwise noted)

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality[1]	Remarks (*Indicates species is agriculturally useful)
Atriplex (cont'd.)					
lentiformis (Torrey) Watson	Quailbrush, lenscale, Nevada saltbush	Southern Utah and Nevada and Sonora, Mexico	6-15	3	High tolerance for alkali and saline soil (Benson and Darrow, 1954, p. 121; Magistad and Christiansen, 1944, p. 10). Fair browse plant. Reaches height of 10 ft. where water table is shallow (Kearney and Peebles, 1951, p. 259).
Cnilopsis linearis Sweet	Desert willow	Western Texas to southern Nevada, Arizona, southern California	To 50	--	May not always occur as a phreatophyte (Bryan, 1925).
Distichlis stricta (Torrey) Rydberg	Saltgrass, or desert saltgrass	All Western States (Hitchcock, 1951, p. 178)	2-14	1-3	*Associated with capillary fringe which reaches land surface.
Elymus condensatus Presl.	Giant wildrye	All Western States except New Mexico	1-12	1-2	(Fair forage. Killed by overgrazing Extensive root system.
cinererus Scribn. and Merr.	Great Basin wildrye	Western United States	To 11	1-2	*Good to fair forage. Found roots associated with capillary fringe in Montana (Consolodation Coal, 1981).

TABLE C-1

SOME PHREATOPHYTES OF THE COAL REGIONS OF WESTERN UNITED STATES (Continued)

(Data from Robinson (1958) unless otherwise noted)

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality[1]	Remarks (*Indicates species is agriculturally useful)
Fraxinus velutina Torrey	Velvet ash, Arizona ash	Southwestern Utah, southern Nevada, California, Arizona, New Mexico, and western Texas	--	1	Prominent streambank and canyon tree; restricted to areas with a permanent ground-water supply (Benson and Darrow, 1954, p. 237, 274).
Juncus balticus Willdenow	Wirerush, wiregrass	Western United States	--	--	*Grows in wet sites where ground-water is shallow, also in shallow ponds. Appears to occur both as phreatophyte and hydrophte. Deep root system. Fair to good forage.
Juncus cooperi Engelmann	Desertrush	Southern Utah to California	--	2-3	Occurs on the margins of salt marshes and alkaline meadows, common in Death Valley, CA, along the edge of the playa often associa-ted with saltgrass.
Leptochloa fascicurlaris (Lamarck) A. Gray	Sprangletop	Western United States	--	1-3	Occurs along ditches and in moist waste places, often in brackish marshes (Kearney and Peebles, 1951, p. 123(; most places in alkali plains (Tidestrom, 1925, p. 83).

TABLE C-1

SOME PHREATOPHYTES OF THE COAL REGIONS OF WESTERN UNITED STATES (Continued)

(Data from Robinson (1958) unless otherwise noted)

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality[1]	Remarks (*Indicates species is agriculturally useful)
Medicago satiya Linneaus	Alfalfa	Western United States	4+	1-2	*See case study in this appendix.
Populus spp.	Cottonwood	Western United States	--	1-2	Riparian species found along watercourses.
Populus tremuloides aurea Tidestrom	Quaking aspen	Mountainous areas of Western United States	--	1	Considered a phreatophyte when it grows along streams, around springs, and in other wet areas. Shallow root system.
Potentilla fruticosa Linneaus	Bush or scrubby cinquefoil	Locally in Idaho but widespread in Oregon, Washington, Utah, Nevada, and Arizona	Shallow	--	Occurs as a phreatophyte in Pahsimerol Valley, Idaho (Meinzer, 1927, p. 60). Grows in subalpine meadows, along streams, about cold springs in peaty, sandy or clayey loam
Salicornia rubra Linnaeus	Glasswort	Colorado, New Mexico, Nevada, Utah	--	3	Some value as waterfowl feed.
Salix spp.	Willow	Western United States	--	--	Riparian species found along watercourses.
Sarcobatus vermiculatus (Hook) Torrey	Big greasewood	Western United States	60+	--	Roots found on contact with ground water along Squirrel Creek, Montana (Consolidation Coal 1981). Generally associated with shallow ground water. Alkaline tolerance.

TABLE C-1

SOME PHREATOPHYTES OF THE COAL REGIONS OF WESTERN UNITED STATES (Continued)

(Data from Robinson (1958) unless otherwise noted)

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality[1]	Remarks (*Indicates species is agriculturally useful)
Spartina perctinata Link	Cordgrass	Montana to New Mexico	--	1-2	Requires water table close to the surface. Is often considered a hydrophyte.
Sporobolus airoides Torrey	Alkali sacaton	Western United States	5-25+[2]	1-3	*Most common in the Southwest, where it is important as forage; deep, coarse root system. Prefers moist alkali flats.
Suaeda depressa Watson	Seepweed, saltwort	Southwest	--	3	Browsed when other forage is scarce. Occurs on saline or saline-alkali soils.
Tamarix aphylla Linneaus	Athel tree	Southwest	--	1-3	Introduced species found where water table is close to the surface.

[1]The quality of the ground water with respect to its suitability for crop growth is indicated by numerals, as follows: 1, excellent to good; 2, good to poor; 3, poor to unsatisfactory.

[2]Meinzer, 1927.

In mapping vegetation communities, the Soil Conservation Service classifies rangeland according to climax vegetation, soil, and climate. Four types of range sites can be considered potentially subirrigated. These rangesites produce more herbage than ordinary range uplands because of superior soil moisture availability and are defined (after Zacek and others, undated):

> WETLAND: Lands where seepage, ponding, etc., raise the water table above the surface during only a part of the growing season. Too wet for cultivated crops, but too dry for common reed, cattails, or true aquatics.
>
> SUBIRRIGATED: Lands which have an effective subsurface ground-water table and water rarely over the surface during the growing season.
>
> SALINE LOWLAND: Subirrigated and overflow lands, where salt and/or alkali accumulations are apparent and where salt-tolerant plants occur over a major part of the area.
>
> OVERFLOW: Areas regularly receiving more than normal soil moisture because of run-in or stream overflow.

Each of these rangesites frequently have plant species which may be subirrigated.

Regulatory Considerations

Subirrigation can occur under a range of conditions with a corresponding range of plant productivity induced by available ground water. The interplay of fluctuating water table elevations, land surface elevation, soil properties, and annual water supply variations causes changes in water availability from place to place in different years. The best subirrigated areas are those where plant roots have

ground water accessible to them during the entire growing season. These plants experience limited moisture stress, and their life cycles tend to be longer than those of upland plants.

In other areas plants may benefit only a little from subirrigation because available water is only accessible for a short time. In terms of the alluvial valley floor regulatory program, subirrigation occurs if enough water is available for a long enough time to have a recognizable effect on the species type and the productivity of a plant community. Agricultural crops or rangeland must receive enough subirrigation that the community is notably more productive or more agriculturally useful when compared to dryland areas.

Various problems have been encountered in the past by regulatory and industry personnel in defining subirrigated and non-subirrigated areas. These difficulties, some of which are described below, have been experienced because the regulatory process requires that areas of marginal or occasional subirrigation must be classified as either subirrigated or not subirrigated. The regulatory process necessitates a definite delineation of subirrigation and non-subirrigation areas, when, in fact, such arbitrary delineation of these areas is not definitively accurate.

Water supplied by subirrigation is recharged by ground water and not by local infiltration of precipitation, surface runoff, or snowmelt. Areas which are naturally wet because of poor drainage

conditions or because of extra snow accumulation may be exceptionally productive but are not subirrigated. Sometimes, subirrigated areas are also flood irrigated, and determining the relative importance of each can be difficult. For identification purposes, the distinction of water source between surface and ground water is not important, because either fits the regulatory definition of water availability. For puposes of understanding essential hydrologic functions, however, an estimate of relative surface- and ground-water contributions is important.

The timing of water availability affects the usefulness of subirrgation. High water tables tend to coincide with periods of seasonal high runoff or high precipitation. Thus, at times when the potential for subirrigation is at its highest, a plant's entire moisture requirement may be met by shallow water recharged from rainfall or diverted floodflows. By the time this water in the upper soil zone is depleted, the water table may have dropped below the root zone. In this case, the only benefit of a raised water table is that soil moisture in the lower root zone has been recharged for later use by plants. In a regulatory sense, subirrigation would not be demonstrated here unless the species composition or annual productivity could be substantially differentiated from those in other areas.

In some situations, subirrigation may provide enough water to maintain alfalfa but not enough to enhance its production. In years

when above average precipitation or surface irrigation is available, the alfalfa may have significant production; however, in drier years, it may not be important. For example, subirrigation ensures that the plant does not die, but it does not contribute to the plant's useful production. In this case, subirrigation would not exist in a regulatory sense because no increased production would result from the available ground water.

The value of subirrigated land and even the existence of subirrigated land should thus be evaluated by comparing vegetative production data. However, getting production data which yield meaningful analyses can be difficult. For instance, production data provided by a rancher usually are given on a per field basis and may not differentiate production from different parts of a field covering different terrace levels. Vegetative sampling by clipping is a standard technique used by botanists that may be helpful. Production data collected in one sampling year can be compared to average historic data for the farm or region, but a nonaverage precipitation year may result in uncertain (inaccurate) comparisons.

Mechanics of Subirrigation

To fully understand subirrigation, one must consider the various components and processes of the soil/water system and how these components and processes are interrelated. Ideally, subirrigation occurs because plant roots penetrate the soil zone recharged by ground water. Downvalley flow of ground water in the alluvial aquifer

supplies a continuous source of water. Capillary rise of the ground water increases the soil moisture reservoir in the soil above the water table. Roots within the saturated (or partially saturated) soil zones supply additional water to plants supplementing near-surface water supplied by surface infiltration (fig. C-2).

The following discussion describes these soil/plant/water interactions and how each affects subirrigation and productivity of the plant. First, the hydrology of the soil system is discussed in terms of saturated flow in the ground-water system and the capillary rise of water above the water table. Second, the characteristics of soil which hold and supply water to the plant are described. Third, the physiology of roots is discussed in terms of water uptake. Fourth, evapotranspiration and the plant growth cycle are reviewed. The discussion attempts to highlight issues which have been important in recent alluvial valley floor determinations.

A. Alluvial Ground Water. The source of water for subirrigation is the ground water which flows through the unconsolidated alluvial deposits of the valley. This ground water flows under saturated conditions downstream, parallel to the valley. This ground water is found at the base of the unconsolidated deposits, and the geologic deposits in which the water is found is called an aquifer. The compositions of these deposits are discussed in appendix A. Depending on the stratigraphy of the deposit, alluvial ground water may or may not be confined in the aquifer. If the water is unconfined, then the

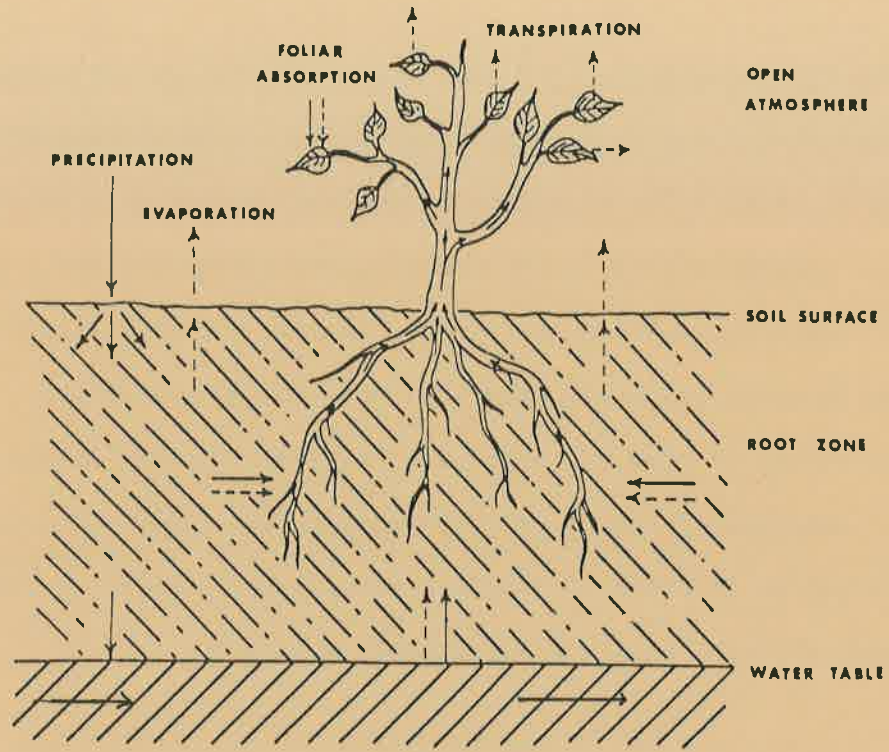


Fig. C-2 Water flux pathways in the soil-plant-atmosphere continuum. Solid arrows represent liquid water fluxes; dashed arrows represent vapor fluxes.

water level rises and falls with changes in volume of flow. If the water is confined (for example, by a layer of clay), then the water level may not change with changes in flow volume.

The source of alluvial ground water at any specific location may be from any one of the following:

1. Infiltration of surface flow through the channel bed and banks to the alluvial material.
2. Lateral or upward ground-water flow from bedrock aquifers which bound the alluvium.
3. Infiltration from manmade structures, such as irrigation ditches or impoundments.
4. Infiltration of rainfall, snowmelt, or surface runoff.
5. Ground-water flow through the alluvial aquifer from upstream areas, whose source of water is one of the previously mentioned items.

In many alluvial systems, the quantity of ground water decreases during the dry summer months (fig. C-3). As the ground-water volume decreases, the thickness of the saturated zone may decrease; thus, the depth from the surface to the saturated zone may increase. If the depth to water increases enough, water that was once available to plant roots may no longer be so. Therefore, subirrigation may cease.

An example of an alluvial aquifer and its characteristics is that of Squirrel Creek, tributary to the Tongue River, in Big Horn County, Montana. Fig. C-4 illustrates a cross section which is typical of

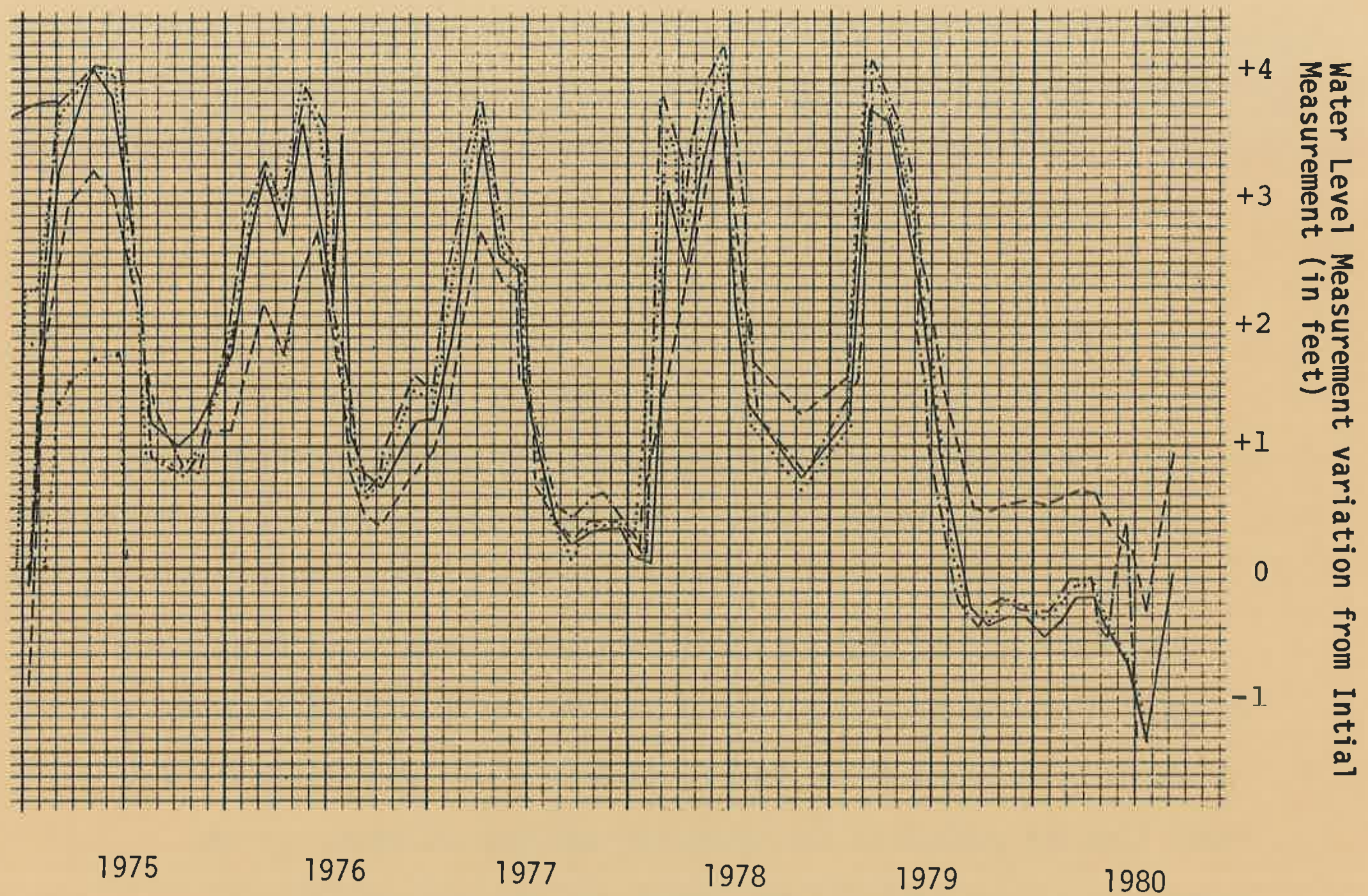


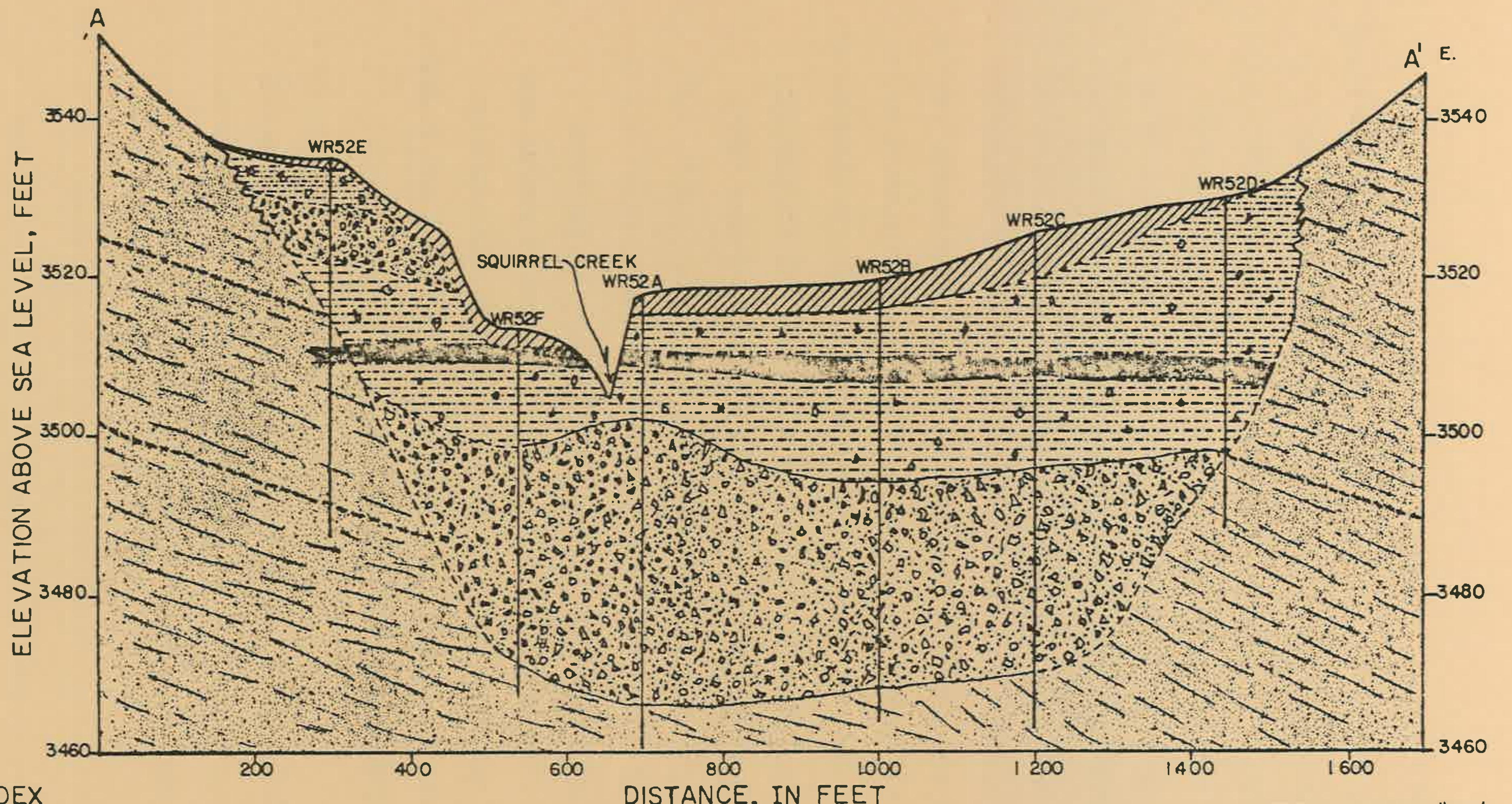
Fig. C-3. Hydrographs from alluvial wells in alluvium of East Fork Armells Creek, Colstrip, Montana. Note seasonal fluctuation of water table (Western Energy Co.).

this alluvial aquifer. The basal alluvial gravel unit is up to 35 feet thick, and most of the ground water in the alluvial aquifer flows through this gravel layer. Ten to thirty feet of fine-grained deposits overlie the gravel. The elevation of the water table fluctuates seasonally but is always within the fine-grained unit. Subirrigation occurs where the land surface is low enough to allow root penetration to the capillary fringe above the water table.

B. Soil Moisture. Soil moisture is recharged by infiltration from the ground surface and by capillary rise of water upward from the water table. Subirrigation occurs if plants use soil moisture moving upward from the saturated ground-water zone. The area of unsaturated, but available, water above the ground water is called the capillary fringe. Capillary water occurs in this area as continuous films around soil particles with the water held by surface tension. Water molecules are drawn upward from the saturated zone by the attractive force, called capillarity, between the soil particles and water molecules. This attractive force exceeds the force of gravity and, therefore, results in upward movement of water. Because capillary water is held by the soil particles under tension, it is more properly called soil moisture and not ground water.

The height of capillary rise of water is dependent on the size of pores between individual soil particles. Large pores, as found in sand, give the least rise. The small pores of clay soils give the

Fig. C-4. Geologic cross-section through Squirrel Creek valley, Decker, Montana, (Consolidated Coal Co.).



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VERTICAL SCALE IS 1"=20'
HORIZONTAL SCALE IS 1"=200'

greatest rise. The importance of the different heights of rise is somewhat offset by the tendency for clay soils to hold water more strongly, preventing moisture from becoming available for uptake by plant roots. Silt-sized pores give the greatest effective height in terms of both absolute height and availability (Dollhopf and others, 1981a). Height of capillary rise has been calculated by Kohnke (1968) and Slatyer (1967) for various soils.

As the attractive force between soil and water in the capillary fringe becomes greater with increased height above the water table, plant roots have more difficulty drawing water. Also, water is supplied at a slower rate to the top of the capillary fringe. For both reasons, then, the upper part of the capillary fringe is less useful to plants than the lower part. This principle has been demonstrated by Wind (1960) and Gardner (1965).

Gardner (1965) demonstrated that in a sandy loam soil, capillary rise of water was able to supply about 0.8 cm of water per day when roots are within 90 cm of the water table. This amount is about equivalent to the daily evapotranspiration (ET) requirement of alfalfa in the Central Great Plains (Blad and Rosenberg, 1974; Rosenberg, 1969a, b). As the distance between the root zone and the water table increases, the amount of water supplied by capillary rise decreases (fig. C-5).

The rate of rise of capillary water has been calculated by Wind (1961) (fig. C-6). In a coarse-textured soil he calculated that capillary rise could supply 5 mm of water per day to a height of 57 cm and 1 mm/day to 87 cm. A very fine-textured soil supplies 2 mm/day to only 40 cm above the water table. The plant's ability to utilize this soil moisture is of course dependent on the depth at which the capillary fringe terminates and the quantity of roots present.

Several degrees of soil moisture content are generally recognized in relation to agricultural and laboratory studies of soil. The wilting point is that moisture content at which permanent wilting of plants occurs. Experiments have proved that this is not a unique value; rather, it depends upon the plant, the climate, the root system, and the volume of soil tested. Branson and others (1976, 1979) have documented the variability of the wilting point of different species found in the semiarid West. The soil moisture tension at which wilting occurred in 12 species ranged from 7 bars (atmospheres) to as high as 96 bars, depending on the rate of consumptive use of water, soil salinity, and soil texture. Typically, 15 bars is used as the wilting point when more specific information is not available for a specific species (Brady, 1977) (fig. C-7).

Field capacity is defined as the amount of water held in the soil after excess water has drained from the soil by gravity. This water is held by capillary forces in narrow spaces between soil grains and

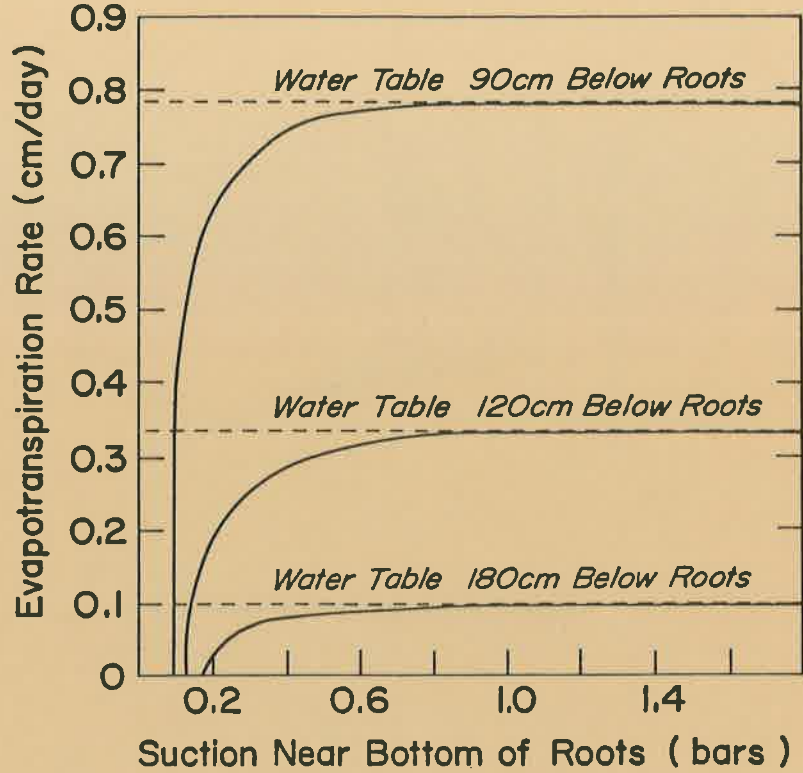


Fig. C-5 Rate of capillary rise, i.e., evapotranspiration, from a water table as a function of the suction near the bottom of the root zone (after Gardner, 1965).

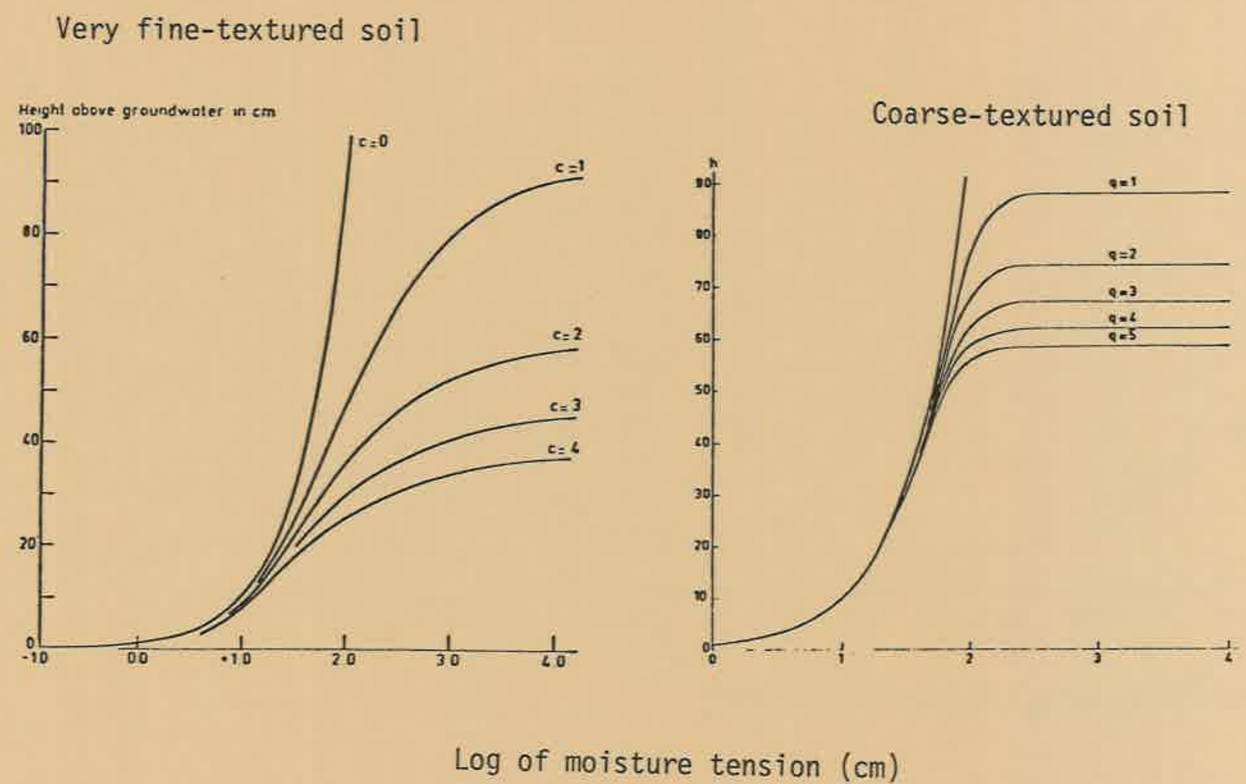


Fig. C-6. Rate of capillary rise to various heights for two different soils.
q is equal to rate in min/day. (Wind, 1961.)

by adhesion of very thin films coating the grains. The tension on soil water at field capacity is usually between 0.1 and 0.3 bars. As roots exert suction through evapotranspiration processes, water is removed from around the soil particles until the wilting point is reached.

The water which can be removed from a soil profile by plants or evapotranspiration as the moisture content is lowered from the field capacity to the wilting point is called available water. Available soil water can be expressed in terms of soil water potential which is a measure of the force with which the water is held by the soil and the force the plant must overcome to obtain the water. The amount of available water is dependent on the soil texture. Sandy soils have less available water than do fine-textured soils (fig. C-7). Thus, laboratory tests are usually done to determine the percent soil moisture in any soil of a particular texture under certain suction potentials.

C. Evapotranspiration. Evapotranspiration is the collective loss of water from the land surface and from plants. That portion which is lost from the ground surface and from rainwater intercepted and held by the above-ground part of plants is called evaporation. Transpiration is the loss of water from the cuticle or the stomatal openings on the leaves of plants and can be considered a biological evaporation process. Evaporation involves a change from liquid to

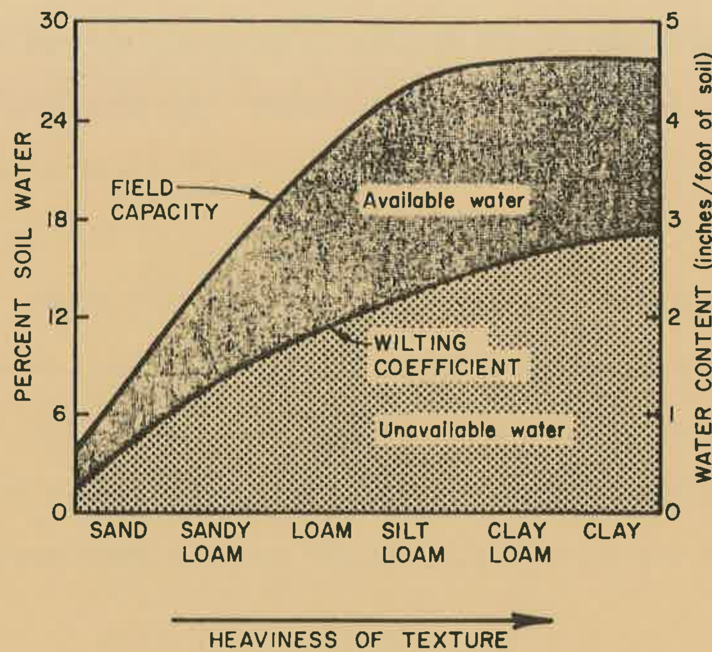


Fig. C-7. Relationship between soil moisture, soil texture, and available water (Brady, 1976).

vapor, and this change requires an input of energy normally supplied by solar radiation. Evapotranspiration is an important concept in understanding subirrigation because it is the upward water loss which occurs in the soil/plant/water budget.

Potential and actual evapotranspiration are terms used to describe water loss from plants. Potential evapotranspiration is the water loss which would occur if there is no water deficiency in the soil. Potential evapotranspiration gives an estimate of the total amount of water which should be supplied by rainfall and irrigation to maximize plant growth. Actual evapotranspiration is the actual water loss from a plant and is usually less than potential evapotranspiration in the West because of the scarcity of water.

The rate at which water is returned from the soil to the atmosphere by evapotranspiration is controlled by two factors: atmospheric demand and soil-water availability. If soil water at the surface or in the root zone is not limiting, ET is equal to the potential rate as determined by air temperature, wind speed, relative humidity, solar radiation, and other meterologic conditions. Most evaporation data have been obtained using evaporation pans placed on the ground, such as the U.S. Weather Bureau's class A pan. The relation between pan evaporation and ET of well-watered crops has been studied for various conditions. A summary of the results is presented by Doorenbos and Pruitt (1974). Results from these studies indicate

that plant transpiration represents roughly 35 to 85 percent of the potential value depending on wind speed, relative humidity, upwind conditions, convection, and pan environment.

Numerous techniques for estimating potential ET in addition to class A pans have been developed, ranging from empiricial equations to physical equations. The latter have been derived from the energy balance of the soil and plant surface, the mass transport of water vapor above the soil and plant surface, or a combination of the two. These methods have been reviewed by Jensen (1973).

Potential ET for vegetated areas is reached only if soil water is not limiting and if plants are actively growing and fully covering the soil. When full cover has not yet been attained, ET will be less than potential ET. As a crop reaches maturity, ET becomes less than the potential ET because the crop no longer is actively growing. Exceptions, of course, are forage crops and other plants that continue to grow actively after full cover is reached.

With continued evapotranspiration, soil-water content declines until it reaches a level where the plant roots can no longer extract the water. The lower limit of soil-water availability to plant roots is the wilting point. Volumetric water content at the wilting point ranges from about 2 percent or less for sands to 30 percent or more for clays. Plants differ in their reaction to decreasing water

contents. For some plants, ET remains essentially at potential rate until the wilting point is reached and then suddenly reduces to almost zero. Other plants show a more gradual reduction in ET as the wilting point is reached. The wilting point will be reached first in the upper part of the root zone, from where it can be expected to advance downward as the deeper roots continue to take up water.

The literature on evapotranspiration is voluminous, and the reader is referred to reviews by Sosebee (1976), Jensen (1973), and Horton (1973).

D. Plant Growth Cycle and Physiology. Probably few environmental factors are as important to the survival of plants as is adequate water availability. Water is the principal consitutent of cell protoplasm, comprising 80 percent of the fresh weight of herbaceous vegetation and over 50 percent of that of woody plants (Brown, 1977). Water is an important component of all plant biochemical reactions, a carrier of nutrients and wastes within the plant, and is essential for the maintenance of cell turgidity and the absorption and dissipation of heat. Numerous discussions of plant-water relationships have been compiled and are readily available (Kozlowski, 1964, 1968a, b, 1972; Taylor and Ashcroft, 1972; Kramer, 1969).

Distribution and movement of water between various constituents of the environment, such as soil, plant, and atmosphere, occur in both the liquid and gaseous phases. A gradient of free energy (or water potential) between these constituents provides the force behind water movement. Water movement in the soil-plant-atmosphere continuum proceeds from higher to a lower free energy. This gradient is steepest in the soil and decreases progressively through the plant system through the leaves and into the atmosphere (Gardner, 1965). The essential feature in plant-water relationships is the internal water balance in plant tissues because the internal water balance controls the physiological processes responsible for growth.

Water absorption by plant roots is generally a passive process. Through this process water is absorbed from the soil in response to transpiration by aerial parts of the plant. As water is lost to the atmosphere by transpiration, leaf-water potential declines and, in turn, develops a gradient down the vascular system to the roots. When the root-water potential falls below that of the soil, water enters the root.

As transpiration proceeds, the gradient between the soil and the plant's root system steepens, and absorption eventually lags behind transpiration. This lag in absorption is due to the resistance to water movement by root cells (Kramer, 1969). With continued transpiration, soil moisture decreases, and the capillary conductivity

of the soil declines, causing even greater absorption lags. Plants can and do control transpiration losses to minimize absorption deficits. The ability to control transpiration rates is one of several adaptive responses to arid conditions. Bliss (1962) found transpiration losses well controlled in alpine plants subject to extreme temperature and solar fluxes. Phreatophytes, dependent on root-ground-water contact for growth and survival, have relatively little ability to control transpiration losses.

Plant-water stress is initiated by the lag in transpiration versus absorption rates. If adequate soil moisture is present, the plant will undergo maximum stress during the day and will reduce this stress (e.g., increase leaf water potentials) at night, when transpiration decreases. If soil moisture becomes limiting, the plant cannot recover from this moisture stress, and leaf potentials will continue to decrease. Eventually, decreasing leaf water potentials result in loss of leaf turgor and increases in transpiration resistance.

Unless additional moisture is provided to the plant, severe stress will eventually occur. The ability of plant species to cope with water stress is another adaptation to arid environments. In all situations, however, water stress causes reduced growth rate, protein synthesis, and reductions in other biochemical mechanisms. Under severe stress, biochemical processes will stop, the cell protoplasm

will collapse, and ultimately death will occur. From the perspective of evaluating moisture stress in subirrigated plant species, a loss of soil moisture to these plants will cause growth losses and, ultimately, plant death more readily than in their counterparts on upland sites adapted to soil moisture stress.

Quantitative Assessment of Subirrigation

The amount of ground water used by vegetation has been evaluated with various techniques. Major issues which this research has addressed are the consumption of scarce water resources by flood plain phreatophytes in the arid Southwest, productivity of commercial crops in relation to depth of water, and percent use of ground water by subirrigated species. These studies are usually undertaken for purposes other than to identify areas of subirrigation but may be used to quantify the subirrigation component supplied to a plant community. As such, these techniques are usually used in detailed scientific research, and their application in the study of alluvial valley floors would be limited to detailed assessments of the importance of subirrigation to a specific plant community. Techniques for studying these topics are reviewed below.

A. Lysimeters. Lysimeters are used to obtain a direct measurement of evapotranspiration. A block of soil is held in a porous-bottomed tank, called a lysimeter, and buried in the ground. Water-table depths and net input or drainage of water from the soil

block can be measured. Evapotranspiration is evaluated by measuring the decrease in weight of the soil block or by measuring the water added to maintain a specific water-table depth (McDonald and Hughes, 1968; Robinson, 1970). Lysimeter studies are applicable to studies determining the water consumption and productivity of plants grown under varying soil moisture and water-table conditions. Productivity data from lysimeter studies and from valley bottom vegetation can be compared to make inferences about the water available to the valley bottom vegetation. Such studies should be carried out with containers in the same environment as that of the actual phreatophytes to minimize advective energy loss, or clothesline effect, which could greatly increase the water use of the plants in the lysimeters. Even then, the results are not always transferable to flood plains with different types of phreatophyes with varying rooting depths and different soil profiles.

B. Water Balance Approach. Field techniques to evaluate ground-water use by phreatophytes on flood plains have included measurement of the various components of the hydrological balance. All inflow and outflow components of a certain reach of stream and its flood plain are measured or calculated. The water loss to evapotranspiration is then the difference between the total inflow and outflow. The disadvantages of this method are that large areas are required to obtain a measurable difference between inflow and outflow, and that the errors of the individual components accumulate in the calculated value of the water use (Van Hylckama, 1974).

Dollhopf and others (1979, 1981a) have used the water balance approach to calculate the amount of subirrigation in alfalfa and wheat crops located at various heights above the water table. The water budget developed in this study was for the inputs and consumption of water by the vegetation and not for the hydrologic system.

C. Color Infrared Photography. Jones (1977) presented a method for efficiently measuring evapotranspiration rates over large areas. The method involves correlating optical densities of vegetation on color infrared photography with ET data derived from field study of that vegetation. ET rates for other valley bottom vegetation can then be determined by comparing optical densities with the reference areas. This method thus quantifies various hues of the photography and is useful to extend detailed field study from a limited area to a much larger area. The degree of subirrigation can be determined from photographs taken during normal moisture stress periods and knowledge of the water budget of the plant community.

D. Other Methods. Other field techniques consist of calculating ground-water uptake by phreatophytes from decreases in ground-water flow (measuring gradients and transmissivities in the aquifer); from measurements of the fall of the water table or of decreases in water content of the unsaturated soil zone; and from increases in ground-water salinity. Reasonable agreement between the results of these methods has been reported (Gatewood and others, 1950).

Case Study of a Subirrigated Alfalfa Field

A study was made of an alluvial valley to determine the importance of subirrigation to agriculturally significant crops and illustrates the type of analyses possible in alluvial valley studies. Dollhopf and others (1979, 1981a) related the yields of alfalfa and wheat to varying amounts of subirrigation as a function of location in the valley and its sideslopes. Of particular interest is their work on alfalfa grown for forage and for seed because of the alfalfa's naturally deep roots and the importance of this crop throughout the coal regions of the West.

The root distribution of an alfalfa plant is important in the plant's ability to tap deep ground water. Dryland alfalfa plants in Montana will generally root in the upper 10 feet of soil and extract the bulk of its water requirements from the upper 13 feet of soil (Brown, 1971, 1972). Although the majority of roots are within the top 4.6 feet of soil, the tap root, which extends deeper, is characteristically covered with small root hairs which give a large effective surface area for uptake of soil moisture and nutrients. Alfalfa roots have been noted at depths of 65 feet, 66 feet and 129 feet by Meinzer (1927, p. 54) and 30 feet by Hughes and others (1962), but these examples are atypical and do not indicate normal root patterns.

Dollhopf and others (1979, 1981a) studied alfalfa growth near Colstrip, Montana. The presence or absence of subirrigation was documented by measurement of the soil-water content of the profile and observation of diurnal fluctations of ground-water level. Further confirmation and quantification of subirrigation was provided by evaluation of the hydrologic budget. The hydrologic budget in this study was made by measuring the difference between inputs, such as precipitaion, and outputs (losses) due to evapotranspiration, runoff, and deep drainage. Because all components of the water balance except subirrigation could be measured, the amount of water used by alfalfa derived from subirrigation could be calculated.

Hydrologic balance calculations for alfalfa at sites with water table depths of 18 feet, 40 feet, 44 feet, and 60 feet indicated no reliance on subirrigation. These water table depths are well beyond the normal rooting depth of alfalfa. At other sites with ground water 5 to 12 feet below the surface, alfalfa extracted at least one-third of its water requirement from ground water. On the average, subirrigation supplied a large portion of the water requirements of alfalfa at these sites not supplied by precipitation. At one intermediate site, which had ground water at 15.8 feet and an effective capillary fringe bringing water to 11.3 feet of the surface, seed alfalfa had 25 percent of its water deficit satisfied. The yields from this intermediate site were found to be between those from

the subirrigated sites and those from dryland sites (Dollhopf and others, 1979, 1981a). Results from the 1979 Dollhopf study are summarized in fig. C-8.

Dollhopf and others (1981a) developed a hydro-yield relationship (fig. C-9) which can be used to estimate the yield variation of alfalfa in an alluvial valley system if ground-water level fluctuations occur. The hydro-yield relationship suggests that when the ground-water level is deeper than 15.8 feet, or when the effective capillary rise plus ground-water level is deeper than 15.8 feet from the surface, alfalfa will not be subirrigated. Although these results were developed in Colstrip, Montana, they may be applicable to other sites in the Northern Great Plains (Dollhopf and others, 1981a).

Mapping and Studying Subirrigated Areas

The regulatory need to designate alluvial valley floors with definable boundaries results in the necessity of mapping subirrigated areas. Natural systems do not usually yield clearly fixed boundaries, as are desired for regulatory purposes. In subirrigated areas, a frequently observed pattern is an area of clearly subirrigated vegetation, a zone of clearly not subirrigated uplands, and a zone of limited subirrigation, which decreases in importance as one moves away from the stream channel. The greatest difficulty in mapping subirrigated areas is in drawing a line in the midst of the zone of uncertainty.

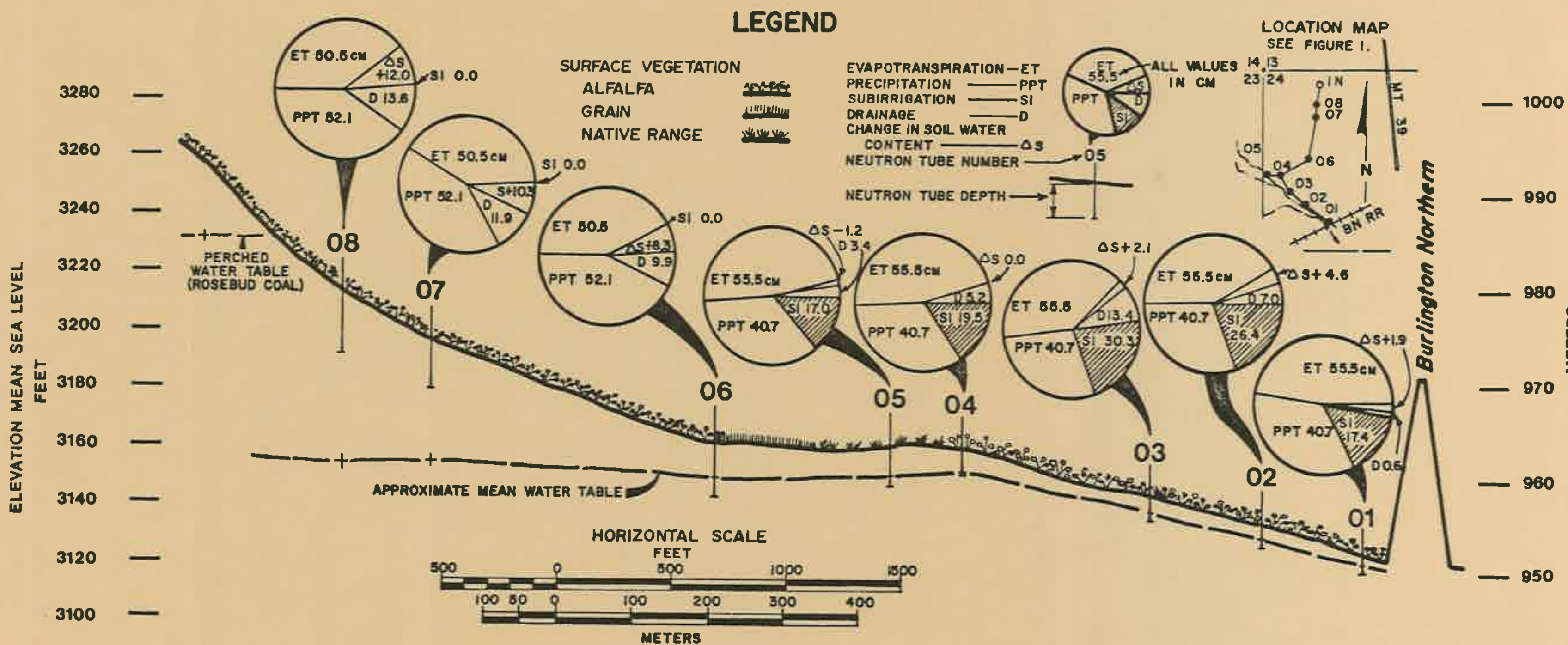
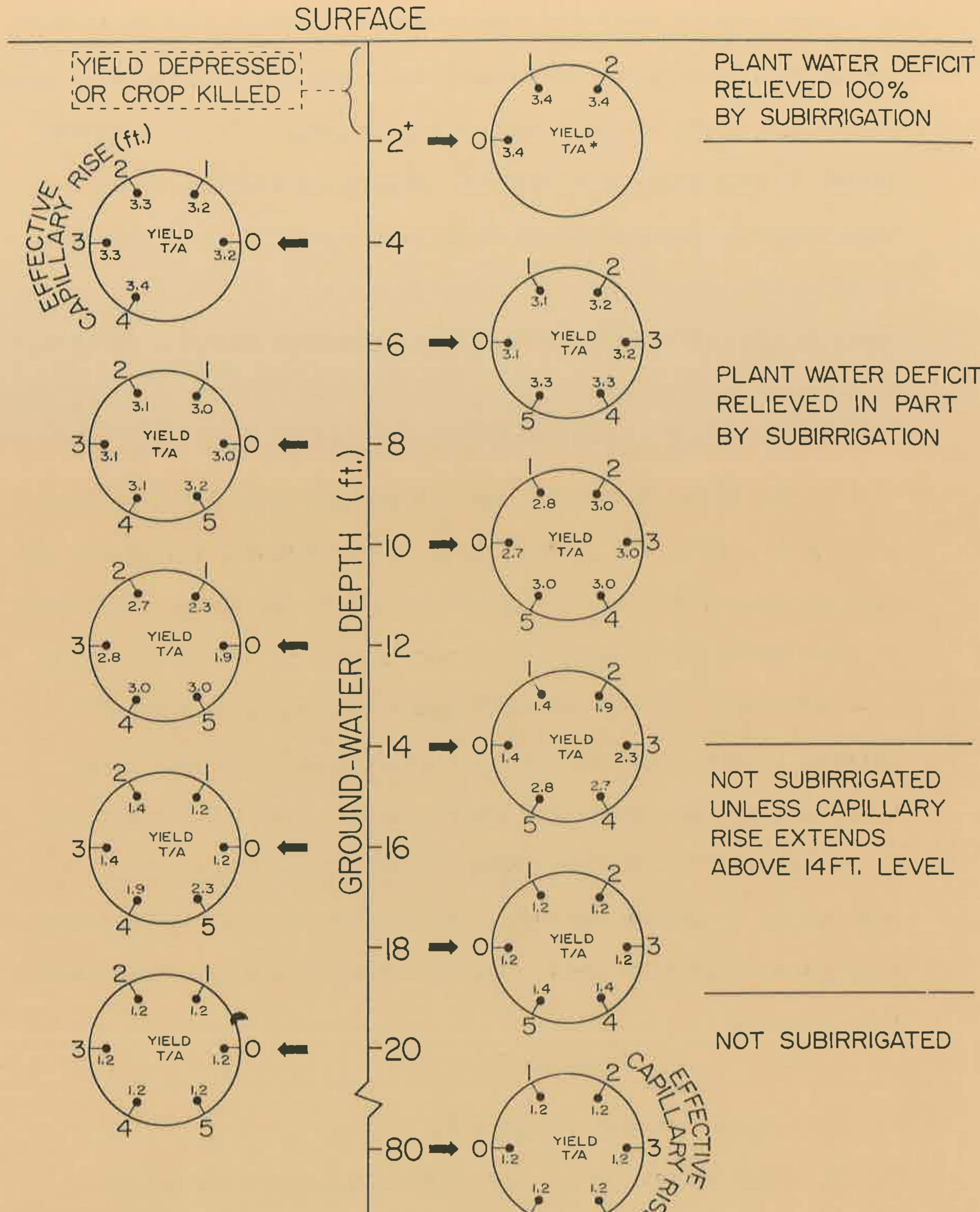


Fig. C-8. Hydrologic budget for the cropland area in Coalbank Coulee watershed as a function of depth to ground water. Sites 01-05 represent a 4-year summary (1975-78), whereas sites 06-08 represent only the 1978 hydrologic year. (Dollhopf and others, 1979).



+ 1 foot (ft.) = 0.3 meters (m)

* 1 ton/acre (T/A) = 2,242 kilograms/hectare (kg/ha)

Fig. C-9. Relationship between alfalfa yield, ground-water level, and effective capillary rise in an alluvial valley system. (Dollhopf and others, 1981.)

This section describes some methods frequently used to identify and study subirrigation and some of the questions which must be asked before boundaries of subirrigation can be drawn. There is no easy answer in assessing subirrigation. Drawing conclusions about subirrigation should be based on an analysis of several lines of evidence and cannot always be based on a single factor, such as the depth to the water table or an office inspection of color infrared photographs.

As the distance between land surface and water table increases, usually in a direction perpendicular to the channel, the amount and rate of water which can be supplied to plants decreases. The number of days during the growing season when useful subirrigation occurs also decreases. As the amount of water supplied decreases, the amountof ground water available for plant growth decreases, and subirrigation may simply keep plants alive. However, subirrigated areas must still be mapped. Many studies of subirrigation use a combination of several methods to differentiate subirrigated areas from non-subirrigated areas. The following methods are described in this section:

A. Color infrared photography.
B. Identification of roots within the capillary fringe.
C. Vegetation mapping (community types or indicator species).
D. Agricultural or vegetative production.

E. Rooting depth determination.

F. Maximum water table depth.

G. Soil mottling.

H. Streamflow increase or ground-water rise after the first killing frost.

I. Diurnal fluctuation of the water table.

Color infrared photography is the most useful method for reconnaissance identification and mapping of subirrigated areas. The other methods can be used to verify the existence of subirrigation. These studies can also aid in the determination of essential hydrologic functions in subirrigated valleys to sort out ground-water contributions from other water sources, and to establish the mechanisms of subirrigation in order to develop adequate reclamation.

A. Color Infrared Aerial Photographs. Aerial photographs taken with color infrared film can distinguish actively transpiring plantcommunities from those which are senescent. The advantage of color infrared film over other film types for vegetation analysis is the high reflectivity of actively growing plants in the near infrared wavelength range (0.70 to 0.90 micrometers). This high reflectance in the near infrared range is, in part, a function of the water content of the leaves, which, in turn, is a function of the water available to the plant's roots. Due to the three dye layers used in the film, the film yields "false" colors--near infrared radiance generally appears

red, red may appear green, and green may appear blue. The red hues of infrared photography give an indication of both the relative concentration of transpiring plants and the degree to which the plants are not under moisture stress.

Interpretation of color infrared photography can be done visually for the qualitative analyses necessary for alluvial valley floor identification studies. Rigorous interpretation, which might attempt calculation of rates of evapotranspiration, involves classification of colors which must be done with instruments capable of measuring optical densities of the film. This type of work (Jones, 1977) should remain in the realm of academic endeavor, although quantification of subirrigation in studies done for material damage assessments might effectively use it.

A single series of photographs taken late in the growing season or a sequential series taken at intervals during the growing season can indicate vegetation which may be subirrigated. Late-season color infrared photography for all Western coal regions is available from the EROS Data Center in Sioux Falls, South Dakota. To positively identify areas with red hues on infrared photography as subirrigated, the possibility of the existence of any other water sources must be eliminated. This can only be done by field checking the interpretations. If other forms of irrigation, such as flood irrigation, are practiced, then subirrigation cannot be positively

identified and other study methods must be used. Perched water tables, recent rainstorms or other localized contributions to elevated soil moisture may cause plant growth which confuses aerial photograph interpretation of the extent of subirrigation.

B. Identification of Roots Within the Capillary Fringe. Finding a significant portion of a plant's roots within the capillary fringe above the water table is considered evidence of subirrigation. The capillary fringe is normally identified from soil moisture data collected by the neutron-scattering technique (neutron probe). Rooting depths are typically measured in pits dug with a backhoe or similar device. Problems with this technique include inherent drawbacks of the neutron-scattering technique, depth limitations for installing access tubes and digging pits, and difficulty in knowing and identifying a signficiant portion of the roots. If this technique is used carefully, it can provide useful information. As mentioned previously for alfalfa and other plant species with taproots, total rooting depth may not reflect the existence of a signficant portion of the root mass.

Rooting depths can be determined in backhoe pits, although the rooting depths of some phreatopytes (e.g., alfalfa) may exceed the usual depths of pits. What constitutes a significant portion of roots to be found in the capillary fringe depends on the rooting morphology of the specific species. For instance, most of the root biomass of

dryland alfalfa is found within 9.8 feet of the surface, and about 80 percent of these roots are within 4 feet of the surface. However, alfalfa grown for seed production would ideally be grown in a soil in which the top 4 feet of soil becomes depleted of water late in the growing season, thus triggering the plant into a reproductive state and in which the lower profile (6 to 12 feet) contains available moisture to sustain a dense stand of alfalfa (Dollhopf and others, 1981a).

The neutron-scattering technique is based on the principle that hydrogen atoms are the only major cause reducing the kinetic energy of fast neutrons. Hydrogen atoms are assumed to be present primarily in water, and the activity of neutrons is assumed to be proportional to soil moisture content (Shirazi and Isobe, 1975). Use of the neutron probe technique involves calibration of the measuring probe for varying soil textures and moisture contents (Rawls and Asmussen, 1973) and for determination of soil-water desorption characteristics of each soil profile. Thin-walled aluminum access tubes are installed in predrilled holes which are usually about 12 feet deep. Initial measurements made with a neutron moisture probe are compared to the volumetric moisture content samples measured in a laboratory to calibrate the measuring probe for future measurements in the same tube. To determine the relationship between soil moisture content and moisture availability to plants for a specific soil profile interval, the desorption characteristics of the soil interval must be measured

by laboratory techniques (U.S. Salinity Lab, 1954). Error is introduced here because, at the 0.3- and 15-bar tension levels, a different amount of water may be contained in the in situ soil than in the laboratory sample whose original soil structure has been disturbed. Estimation of desorption characteristics is sometimes made from the textural analysis of the sample. Problems encountered in using data collected from neutron probes in alluvial valley floor studies are detailed by Dollhopf and others (1981a, b).

Results of measurement of soil moisture in a soil profile during the growing season are depicted in fig. C-10. Effective capillary fringe water lies in the suction range of gravitational water--that is, between field capacity (-0.3 bar) and saturation (0.0 bar). Capillary fringe height can be estimated as the distance between the ground-water level (measured in an adjacent piezometer) and the level at which soil-water content becomes less than field capacity (Dollhopf and others, 1979, 1981a).

Methods have been devised to determine the actively functioning portion of the root structure. The radioactive phosphorus techniques of Lipps and others (1957) and Fox and Lipps (1955) have proved to be successful in studying root activity zones in alfalfa. The technique involves injecting radioactive P_2O_5 near the root structure at various depths and monitoring the labelled material in the leaf samples. This technique could be expanded to determine root activity zones for other phreatophytes of interest.

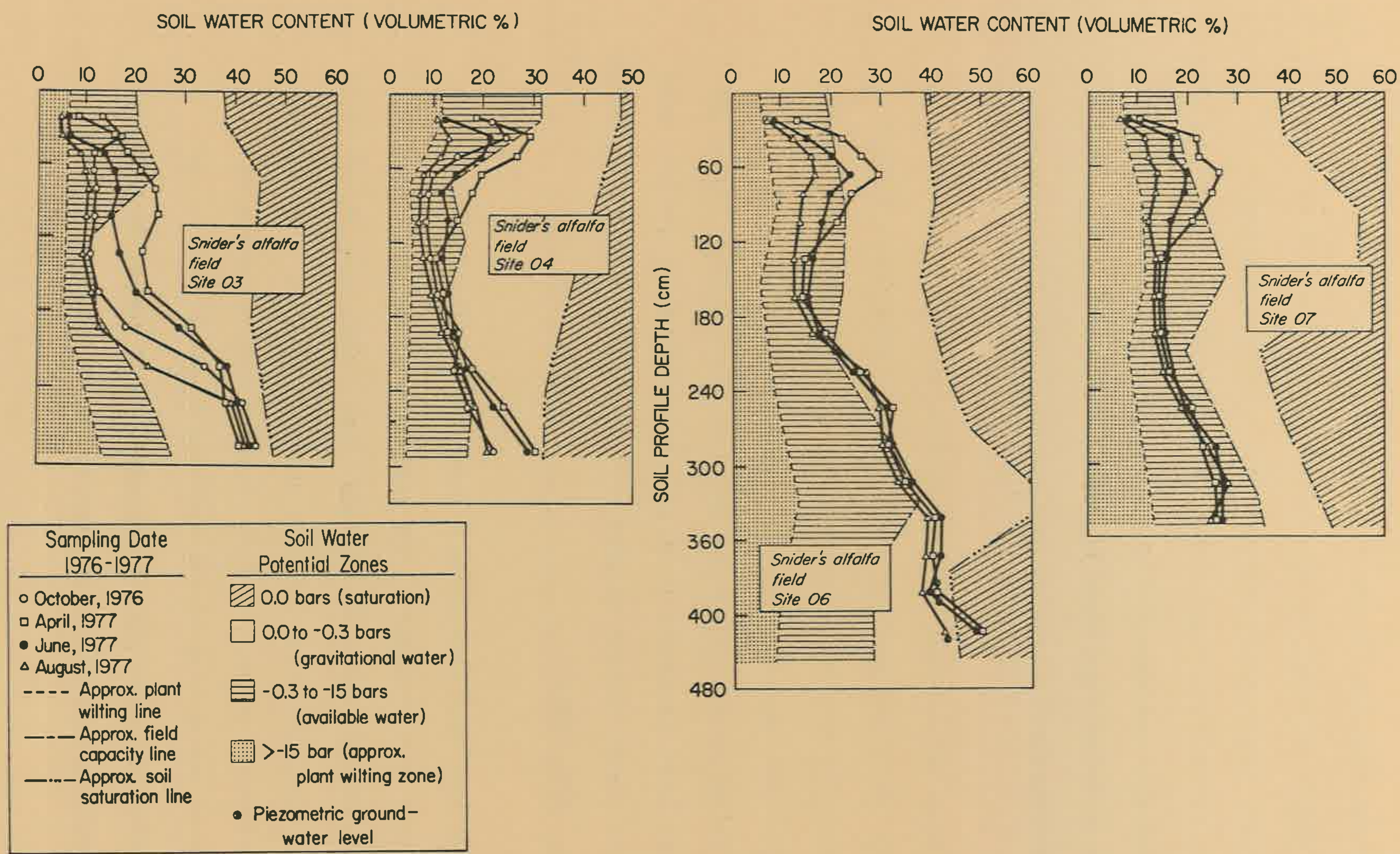


Fig. C-10. Foot zone soil water content as a function of time during the 1977 hydrologic year in alfalfa cropland area of Coalbank Coulee water-shed, Colstrip, Montana. Sites 03, 04, and 06 are subirrigated; site 07 is not subirrigated. Source: Dollhopf and others (1979).

C. Vegetation Mapping. Mapping species which are known phreatophytes produces a vegetation map distinguishing between subirrigated and non-subirrigated species. Use of specific species as indicator species can be misleading, however, because some species, such as silver sage, Western wheatgrass, and alfalfa, occur in both dryland and subirrigated conditions. Sometimes, production data can separate the small yields produced under dryland conditions from the higher yields which would only result from subirrigated conditions. The existence of a plant community which consists of several phreatophytes gives more convincing evidence of subirrigation than the existence of a single phreatophyte.

D. Agricultural Production. Enhanced productivity of subirrigated agricultural crops over dryland crops takes place because of increased soil moisture during all or some part of the growing season. For alfalfa, Bauder and others (1978) have determined that plant water use is a linear function of dry matter production. This relationship can be used to study the amount of subirrigation provided to an area.

Measurements of production of dryland areas versus potentially subirrigated areas are made, and an analysis is made of differences between sites. Comparable values would indicate that subirrigation has a minimum effect on the area in question.

Limitations in this method of analysis pertain to the comparability between sites in terms of crop spacing, age of crop, and crop management differences, such as fertilizer application and harvesting methods. In applying this method to investigate the existence of subirrigation in an area, care should be exercised in comparing only upland and lowland sites with similar crop histories.

E. Rooting Depth Determination. Rooting depths of native and agricultural crops are not always constant across different soil and subsoil conditions. Weaver (1920), in his classic paper on root development and formation, found that there is a certain amount of plasticity to root development under different soil conditions. He noted that alfalfa roots are normally dominated by a single taproot with few lateral branches, but, under heavy clay conditons, the branching habit of the plant becomes much more developed. Because of this plasticity, accurate site information is more important than literature searches in determining the rooting characteristic of potentially subirrigated plant species.

Methods for determining rooting depths and other rooting characteristics are normally accomplished by excavating a trench near the plant in question. Excavating the entire root structure, as Clements (1920) did, is too costly and time consuming. Once trenching is completed, the levels of rooting depths associated with various root diameters can be determined by making root depth-to-surface measurements.

In using this trenching technique it must be kept in mind that the plant's root structure is not going to be completely exposed; rather, the trench will be merely making a longitudinal cut into the soil through which plant roots pass. Therefore, care must be exercised in determining trench placement and the location of the root structures.

Several methods have been devised to quantify root structures at various depths. The SCS method divides roots at fixed intervals into classes representing root density and thickness (table C-2). Another method used in an analysis of rooting depths in the Squirrel Creek, Montana, drainage (Consolidation Coal Co., 1980) describes rooting depths as percentages of root structure biomass found at variable depths (table C-2).

TABLE C-2

ROOTING DEPTH CLASSIFICATIONS

Depth internal	Root density	Thickness
1 foot	M = many roots	VF = very fine roots
	C = common roots	F = fine roots
	F = few roots	M = medium roots
	C = coarse roots	
(Source:	Soil Conservation Service)	VC = very coarse roots

Depth interval	Root structure biomass
v feet	10% above v feet
w feet	25% above w feet
x feet	50% above x feet
y feet	75% above y feet
z feet	100% above z feet

(Source: Consolidation Coal Co.)

It is also possible to simultaneously determine other characteristics of the soil and subsoil during pit excavation. Evidence of soil mottling, increases in soil moisture and texture, and water-table depths may be determined and allow empirical relationships to be made between rooting depths and these variables.

Although roots within the water table or capillary fringe are considered evidence that subirrigation may exist, the importance of subirrigation in terms of enhanced production also needs to be considered. Each plant species will provide a different answer to this question, on the basis of root morphology, soil characteristics, and other physiological requirements. The presence of a water table in contact with some part of the root structure does not, in itself, constitute subirrigation.

F. Maximum Water-Table Depth. If maximum depth of the water table below which subirrigation does not occur is known for a specific species, then the areal extent of subirrigation can be determined by mapping that water-table distance below ground surface, using water-level data collected from observation wells. For instance, Montana Department of State Lands (MDSL, 1981) determined for the Squirrel Creek valley that alfalfa is subirrigated where the water table is within 19 feet of the surface. Data from the extensive array of monitoring wells allowed a 19-feet-to-water line to be drawn to outline subirrigated areas. The 19-foot figure was determined by a

14.5-feet-to-water limit interpreted from research by Dollhopf and others (1979, 1981a) plus the existence of a 4.5-foot capillary fringe in the heavy-textured alluvial soils.

G. Soil Mottling. The existence of soil mottling is used to indicate soils which experience high water tables or which have horizons which impede downward percolation of water. Poor water drainage or constant saturation creates low oxygen content in soils and leads to reducing conditions. Iron and manganese are in the reduced state, and the compounds formed give the typical gray and bluish colors of gleyed (poorly drained) horizons. A fluctuating water table or water content causes variable reducing and oxidizing conditions. Some iron will be oxidized and yellow-brown, brown, and red compounds will be formed. The characteristic colors of reducing and oxidizing conditions, when found together, are described as mottling. Gleying conditions can occur throughout a soil if the water table is high or can be restricted to only a part of the profile if water drainage is impeded (Birkeland, 1974).

Determining the exact cause of soil mottling makes its use as an indicator of subirrigation difficult. Mottling can be caused by a high water table, which would establish the possibility of subirrigation. However, excessive flood irrigation and horizons impeding drainage may also cause mottling. Mottling may also be a relic feature related to hydrologic conditions which no longer exist.

H. Streamflow Increase or Ground-Water Rise After the First Killing Frost. The abrupt halt of evapotranspiration caused by the first killing frost in the fall can cause streamflow to increase and ground-water levels in the alluvial aquifer to rise if vegetation along the valley is subirrigated. This method is useful for determining whether subirrigation occurs in a valley but not for determining the areal extent of subirrigation in the valley.

I. Diurnal Fluctuation of Water Table. The daily fall and riseof the water table in an alluvial aquifer caused by consumptive use of ground water by phreatophytes during the day and subsequent recharge from the upgradient part of the aquifer at night can be measured in a piezometer (fig. C-11). A continuous recorder is normally used to measure water level, and the resulting hydropgraph is corrected for changes in barometric pressure. A diurnal rise and fall of the water table is normally considered evidence of subirrigation. The drawback for assessing subirrigation is that the diurnal fluctuation is most strongly influenced by the areas that are clearly known to be subirrigated; for instance, the central riparian zone of the valley. If the observation piezometers are installed in areas of marginal subirrigation, it may not be clear what the hydrographs mean. Information on diurnal fluctuations may be equivocal. Diurnal fluctuations may sometimes be due to neighboring subirrigated areas, or subirrigation may exist but not be obvious from piezometer measurements, owing to the very low permeability of some fine-grained alluvial soils.

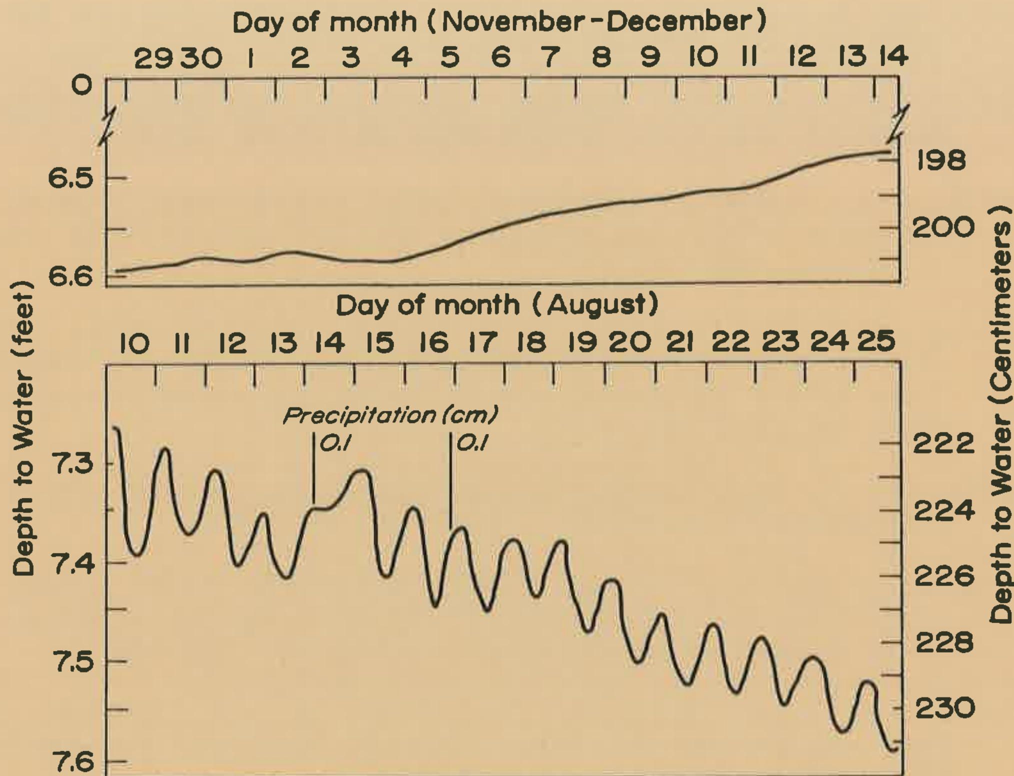


Fig. C-11 Daily ground-water-level fluctuations during two periods of 1978 in the subirrigated cropland area of Coalbank Coulee watershed. (Dollhopf and others, 1979.)

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APPENDIX D

INITIAL STUDIES OF ALLUVIAL VALLEY FLOORS, USING PUBLISHED AND READILY COLLECTED DATA

As described in chapter II, regional appraisals of agricultural use of water in stream valleys, in conjunction with readily collected field data, can be used to make initial determinations of alluvial valley floor status. Use of this kind of data is desirable because many operators, as well as land management agencies, would like to know about the existence of alluvial valley floors as early in the leasing or mine-development process as possible. Also, in an effort to decrease the amount of baseline data collected at a minesite while still achieving the same regulatory objective, it is anticipated that initial studies of alluvial valley floor status will be sufficient for identificaton purposes in permit applications, unless the applicant chooses to collect additional data which clarify the regional pattern.

The following example discusses alluvial valley floor identification in a portion of Kane County, Utah, and illustrates the use of regional agricultural data in making initial determinations.

Regional Setting

This regional identification study (Schmidt, 1980) conducted for the U.S. Office of Surface Mining, Region V, provides an instructive case study because the project was conducted in an area where no previous alluvial valley floor mapping had been done. Some of the

notions about alluvial valley floors in the Powder River Basin are not applicable in this portion of the Colorado Plateau. Therefore, it was necessary to examine the basic role of valleys in the agricultural land use pattern before identification could begin. The process described may therefore be instructive to applicants in coal regions outside the Powder River Basin.

The evaluated area is located in Kane County, Utah, between Bryce Canyon National Park and the Arizona State line. (fig. D-1). The region was studied because some areas had been petitioned by several national conservation groups as being unsuitable for coal mining. The area was informally known as the Alton unsuitability petition area.

The region is dominated by plateaus, cliffs, and canyons and consists mostly of carved tabular relief (fig. B-9). The regional structure and topography are fairly simple, with rock units dipping to the north and revealed as a series of platforms at various altitudes, each bordered by great cliffs. The study area extended from the Paunsagunt Plateau, above 9,500 feet in elavation, to the Kanab Plateau, at about 5,000 feet. This spectacularly scenic area contrasts with the relatively subdued relief of the Fort Union and Powder River Basin coal regions.

The climate of the study area ranges from arid to semiarid, and cool to warm, depending on elevation. At 7,000 feet, mean annual

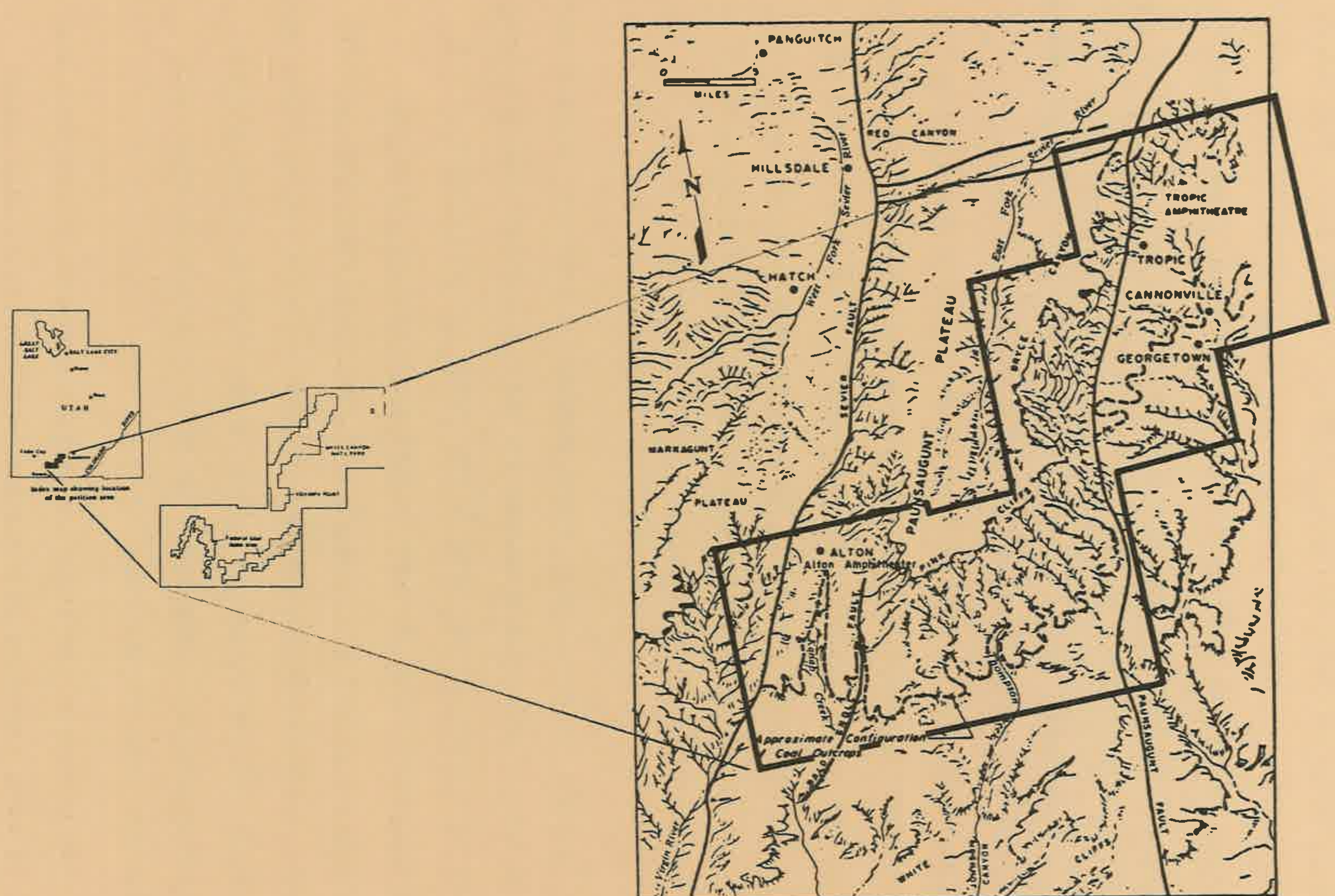

Fig. D-1 Map of southern Utah petition area, showing physiography (OSM, 1980).

precipitation is about 16 inches, whereas at 5,000 feet, mean annual precipitation is about 12.5 inches. The range in the frost-free growing season also reflects elevation differences, from 112 days at 7,000 feet to over 140 days at 5,000 feet.

The season of least rainfall, April to June, is the major growing season in the region. Therefore, farming is not a profitable enterprise without irrigation. Until the advent of ground-water development in the past 10 years, surface water was the sole source of irrigation water. Valleys have been developed because of favorable soils and proximity to water. Agriculture in the region could not exist in its present form without the valleys; therefore, alluvial valleys do exist in the region.

Valleys in the study area are generally entrenched, often as much as 40 feet. Subirrigated meadows are limited and are usually located close to bedrock springs (fig. D-2). Prior to entrenchment of the valleys, subirrigated meadows existed along many of the stream courses, but ground water was drained from these areas when gullying began. Sagebrush is the dominant vegetation on the valley flats, and, although contributing somewhat more forage than the upland pinyon-juniper vegetation, sagebrush areas are not considered especially productive land for grazing.

Fig. D-2 Headwaters of stream draining Pink Cliffs, Kane County, Utah. This designated alluvial valley floor has subirrigated native grasses.

Agricultural Use Survey and Identification Process

Initial reconnaissance of the area did not reveal an apparent pattern to irrigation use of the stream valleys. Depth of incision did not seem to affect use, and some deeply entrenched valleys were extensively irrigated. The geologic criteria of an alluvial valley floor was not a sufficient basis on which to make determinations, because all valleys, developed and undeveloped, met those criteria. Further investigation was needed to understand water availability in the region and how agriculturalists had developed the area.

The first step in the identificaton process was to map all irrigated lands in the area. Data were obtained from the Utah State Engineer's Office on water rights filings for the area (1974, Proposed determination of water rights in Colorado River drainage area) and the U.S. Agricultural Stabilization and Conservancy Service (maps of farms, crops, fields, and water developments). Interviews were held with personnel of the ASCS, the Soil Conservation Service (SCS), and Bureau of Land Mangement (BLM). In the field, interviews were held with many ranchers and farmers regarding specific developments and the history of water use in the area.

In the timeframe of the project, color infrared photography could not be obtained; however, black and white photos (scale 1:18,500) were borrowed from the SCS. Based on the interviews and interpretation of photos, and field inspection, maps were made of irrigated land, points of diversions, and structures, such as ditches.

All available data were also collected on subirrigated land. These lands are limited in their extent. Maps and interviews held with BLM and SCS personnel were very helpful in identifying these areas. Most stream channel areas are not subirrigated, and the limited occurrence of subirrigated lands is in contrast to their more extensive occurrence in the Northern Great Plains.

The next task was to interpret these data in terms of regional environmental characteristics. All available data on geology, water resources, soils, and vegetation were collected. These studies included soil surveys, land management plans, and geologic and hydrologic appraisals by the U.S. Geological Survey and Utah Bureau of Mines.

On the basis of these data and field observations, a pattern of agricultural use in selected valleys was identified. Virtually all irrigation development in the area is on the larger, but not necessarily perennial, streams. These streams head in the cliffs of the Paunsagunt Plateau, where springs emerge. This area also experiences the most prolonged snowmelt period, which may last into early summer. Irrigation in these valleys takes place where the valleys are wide enough to develop, and points of diversion are located upstream wherever necessary to get water to the areas to be developed.

Waterflow decreases downstream from the high plateaus, even in the absence of irrigation diversion. A pattern of use has developed wherein upper stream reaches are extensively developed. Downstream areas may be less developed, unless (1) a sizeable drainage basins exists, (2) irrigation return seepage is available, or (3) downstream users hold prior water rights.

Aside from designating existing irrigated lands and subirrigated areas in valleys as alluvial valley floors, the central question became the assessment of what valleys have the capability to be irrigated. The present pattern of use is established in water right decrees, however, regulatory determinations of alluvial valley floors are to be based on physical characteristics, not on legal considerations.

Mapped alluvial valley floors have included all valleys whose streams headed in the high plateaus, regardless of whether specific sites were under irrigation. The assumption was made that water could be transported to any terrace level, providing that a part of that level had historically been irrigated. Terrace levels not irrigated by anyone in the region were not mapped as alluvial valley floors, because there was no demonstration of agricultural importance by the regional agricultural community. The upstream limit of designations extended to the area where streams were characteristically diverted.

The most difficult determinations have been related to the status of valleys where the downstream decrease in available water was known. At the reconnaissance level, these areas were still designated alluvial valleys because a quantitative relationship between water availability and irrigation could not be developed. If an applicant wished to propose mining in these areas, however, he would have the discretion of collecting surface water data which might indicate that a site was below the threshold for irrigation development.

This method resulted in the identificaton of numerous stream valleys as not being alluvial valley floors, based on their ephemeral streamflow and the fact that no ranchers in the area irrigated in these valleys (fig. D-3).

Further Considerations

As noted in the chapters II and III, the next stage of identificaiton for a potential applicant would be the collecton of site data, if those data might show that some areas identified as having the capability to be irrigated actually could not be so developed. For instance, water quantity, water quality, or soils data might show that certain areas could not be irrigated, owing to specific physical limitations. If, however, an applicant agreed with the interpretation of the regional pattern, there would be no further detailed investigation needed to identify alluvial valleys.

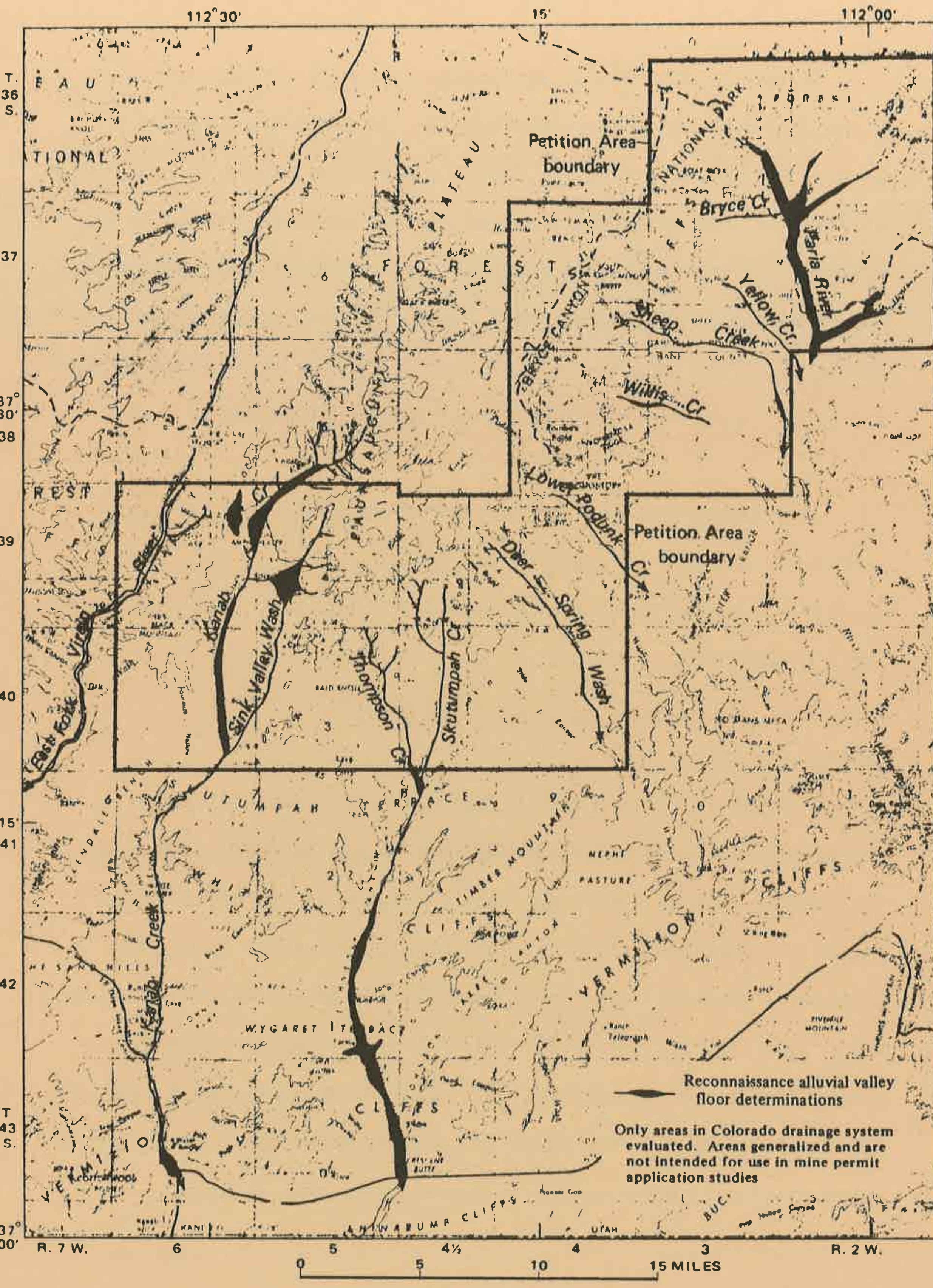

Fig. D-3 Map of the southern Utah petition area, showing identified alluvial valley floors (OSM, 1980).

Identification of alluvial valleys does not imply prohibition from mining. Irrigated areas would have to be evaluated as to the amount of acreage that could be removed from production and still have only a negligible impact on a particular farm's operation. Such assessments would have to consider the specific type of ranching in this part of Utah. Ranchers at the 7,000-foot elevation do not winter any herds in the area, and the production of hay is not for winter use. Instead, cattle are moved every year to lower elevations (particularly in Arizona) for the winter. Hay grown at high elevations is used in the same season or is sold for additional income. Thus, significance evaluations would have to consider lost production in terms of this particular style and economy of agriculture. In a region where winter feed was produced, significance studies often evaluate the effect of lost production on an over-wintering herd. Not so here.

Similarly, evaluations of reclamation feasibility would necessitate more detailed studies of the alluvial valley floors. Virtually all the alluvial valley floors in the Alton unsuitability petition area are irrigated with surface waters. Few areas are subirrigated. Reclamation of surface irrigated lands or lands with the potential to be surface irrigated is substantially less complicated than the reclamation of subirrigated lands.

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APPENDIX E

STRATEGIES FOR RECLAMATION PLAN DEVELOPMENT FOR ALLUVIAL VALLEY FLOORS

Alluvial valley floors can be mined (1) if they are found not to be significant to a farm, or if the area to be mined is of a negligible size, and (2) if the feasibility of reclamation is sufficiently demonstrated. No designated alluvial valley floor has yet been mined and successfully reclaimed; however, several plans for reclamation have been proposed. Insufficient time has elapsed for successful reclamation to have been demonstrated. With time, however, some types of alluvial valley floors will be successfully mined and restored to their premining essential hydrologic functions.

This appendix summarizes some existing industry proposals for alluvial valley reclamation as a guide to development of these plans by other companies. No individual plan should be copied because site-specific conditions will dictate different approaches for each site. This appendix also discusses some general conceptual approaches to alluvial valley reclamation which may help companies begin plan development.

Types of Alluvial Valley Floors

As previously noted, all alluvial valley floors are not the same. Valleys may have different characteristics which result in different essential hydrologic functions and agricultural uses. A

mining and reclamation plan should be patterned after the specific characteristics of the valley in question.

In a general sense, a few "types" of alluvial valleys can be identified:

1. Subirrigated valleys.--These valleys support either rangeland important to a grazing operation or a cropped area. Subirrigated valleys pose the greatest problems for reclamation plan development because of the need to reestablish an alluvial aquifer with adequate water quantity and quality to support the kinds of vegetation which existed before mining.

2. Surface-water-irrigated valleys.--These valleys will be part of an existing agricultural operation, and reclamation will focus on restoring the irrigated land use. Such reclamation involves restoration of stable stream channels, land surfaces, and suitable soils. This kind of reclamation is generally considered easier than restoration of subirrigation.

3. Valleys with the capability to be surface-water irrigated.--These valleys, not now in any "developed" agricultural use, are the easiest to reclaim. The goal of reclamation in such valleys is to restore the physical characteristics which give the valley its capability to be surface-water irrigated. In other words, the stream channel, valley topography, and soils must be restored to their premining condition.

The kind of alluvial valley in question will help focus the kind of reclamation plan necessary to meet the standards of the SMRCA.

Concepts in Reclamation: Stream Channels and Erosional Stability

A. Equilibrium and Threshold. Reclamation specialists have debated the standards, or goals, of reclamation and standards against which to measure success, particularly in the areas of erosional

stability and landscape design. Two concepts, used by geologists, are especially important in developing a focus for reclamation. These concepts are equilibrium and threshold.

Equilibrium is a term that has often been discussed relative to reclamation. Some argue that reclamation landscapes should be restored to "equilibrium" conditions. Over a period of years, a stream adjusts itself, and under equilibrium conditions, the "slope, velocity, depth, width, roughness, pattern, and channel morphology delicately and mutually adjust to provide the power and efficiency necessary to transport the load supplied from the drainage basin without net aggradation or degradation" (Bull, 1979).

More recently, however, Bull (1979) argued that the concept of equilibrium may not be the usual condition of most landscapes. Except for large rivers, which may be in "equilibrium" for hundreds or thousands of years, most streams and other parts of the landscape are usually in transition and are either gradually aggrading (rising, or filling) or degrading (falling, or eroding). In small streams (which are the ones of concern to alluvial valley floor reclamation efforts), periods of aggradation or degradation are probably much longer than equilibrium periods (fig. E-1).

Bull argued that the time span of equilibrium conditions is a small part of landscape history. Streams, in fact, are usually slowly

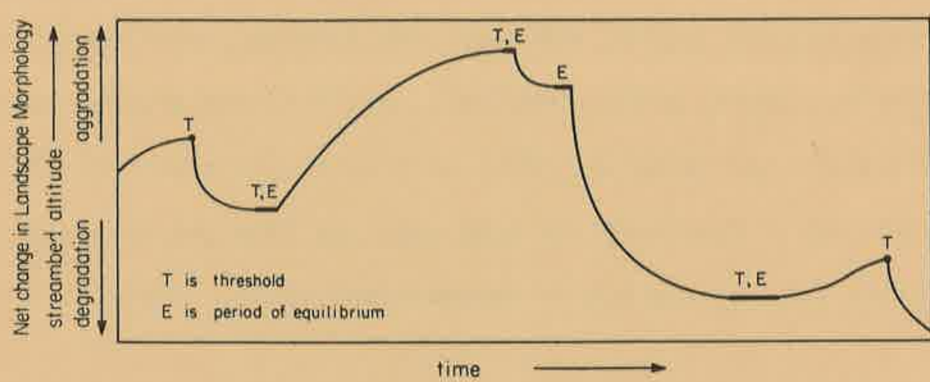


Fig. E-1 Diagrammatic sketch showing differences between threshold and equilibrium concepts for hypothetical stream subsystem. Horizontal parts of curve represent times of no net change in streambed altitude (Bull, 1979).

aggrading or degrading as part of a slow, progressive alteration in the evolution of the landscape. This slow, progressive change occurs because seasonal fluctuations or other short-term events are of greater magnitude than the net response, or change, that occurs during other times of the year. For example, after a large flood deposits a great amount of sediment within a reach of stream, later erosion does not completely erode the deposits; hence, the channel gradually steepens.

Ultimately, steepening may initiate a new response in the system. In this case, the stream may thereafter deepen its channel because its competency (ability to tranport sediment) is increased. Such a change from a previous pattern is called a threshold, or "a transition or point in time that separates different modes of operation within part of a landscape system" (Bull, 1979). Such a change can initiate changes throughout a drainage system.

The history of streams in the Western coal regions reflects this pattern. Periods of aggradation have been interspersed with shorter periods of degradation over the past several thousand years. The alternating sequences have produced the terraced fills of most Western stream valleys. A period of degradation began in about 1880 in many Western valleys. Since about 1960, these valleys have begun to fill again, in an apparent reversal of the earlier downcutting phase. At

presently observed aggradational rates, Emmett (1974) estimated that valley trenches might become filled in 200 to 700 years.

Viewed from this perspective, the goal of reclamation for small stream channels, disturbed and re-created in the course of strip mining, is to reestablish the conditions which return these streams to their former aggradational, degradational, or short-term equilibrium phases. At present, most small streams are in an aggradational phase. Particular care needs to be taken when reestablishing channels that have been determined to be near threshold conditions, since the external changes may initiate a new phase which is not consistent with other parts of the stream system.

Bull (1979) provided several illustrations of threshold changes. Of particular interest here are the threshold changes induced by short-term human impacts. In ephemeral stream valleys in Arizona, flat-floored, gently sloping stream segments support lush vegetative growth. Removal of this vegetation by grazing or fire decreases the roughness of the valley bottom as well as its resistance to erosion. Subsequent development of a small channel, concentrating flow, in such a valley floor initiates a threshold change leading to downcutting of the entire valley.

Patton and Schumm (1975) studied valley floors in the Piceance Basin of northwestern Colorado. They found a relationship between

drainage basin area and valley slope that indicated a threshold for gully development in the area (fig. E-2). Ungullied valleys steeper than the general threshold can be expected to begin downcutting.

Landscapes are not static. Reclamation of stream valleys should consider the ongoing change taking place in the valley (aggradation or degradation) or the equilibrium adjustment in the system. By closely approximating existing landscape features and by considering the mutural adjustment of others, reclamation can be accomplished consistent with processes underway in undisturbed parts of the same landscape.

B. Stream Channel Components. Whether one considers streams from the perspective of equilibrium or thresholds, geologists agree that stream channels adjust to changes in external conditions. Channel adjustment is inherent in either conceptual framework. Channels respond to changes in the amount or timing of delivery of runoff or sediment to them, and channels adjust if one of their interdependent characteristics (width, depth, slope) is changed. If reclamation results in substantial changes in runoff or sediment production or in steepened or flattened slopes, for example, channels adjust to these changes.

The adjustable components of a river channel system include width, depth, slope, roughness of the bed, and pattern. However, the

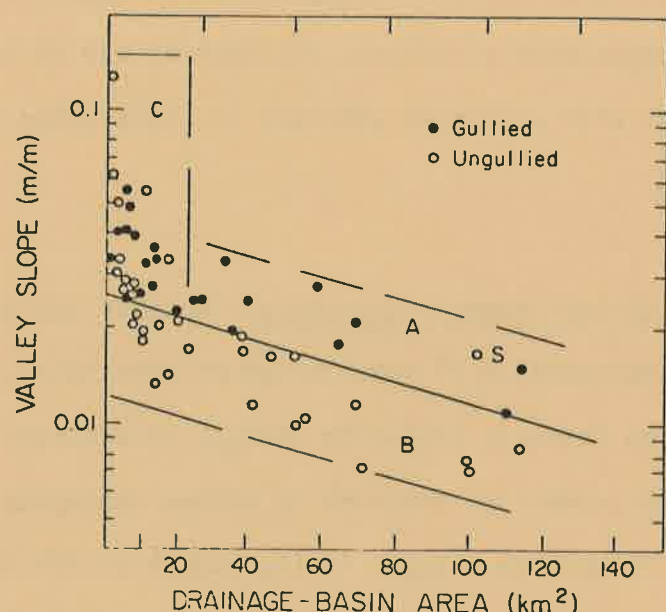


Fig. E-2. Relation of valley slope to drainage-basin area for bullied and ungullied reaches of discontinuous ephemeral stream in Piceance Creek Basin, Colorado (modified from Patton and Schumm, 1975, fig. 2). Solid line is critical-power threshold and separates reaches that have exceeded threshold (A) from reaches that have yet to exced threshold (B). Small watersheds of area C have mixed characteristics owing to greater variability of critical power. Point S is ungullied reach that is considered to be especially susceptible to channel entrenchment.

state of knowledge about channel adjustments is imperfect. Relationships discussed in the literature do not imply that a particular adjustment will, in fact, happen on a particular stream:

> "The principal point to keep in mind throughout any discussion of adjustment of river channels is that usually there are more dependent or adjustable factors than independent ones. It may not be possible to forecast the way in which the requirements are satisfied from the physical or hydraulic requirements alone."
>
> "Unless otherwise specified, the various elements of the channel may be assumed to be equally amenable to adjustment" (Leopold, and others, 1964, p. 257).
>
> "But it is not possible to forecast what will be the effect of a particular alteration. The change of elevation of a river channel is the net effect of complex interactions, and its forecast is beyond present knowledge except under special circumstances" (Dunne and Leopold, 1978, p. 607)."

Thus, careful observation of existing geomorphic, geologic, and hydrologic conditions is necessary in undertaking reclamation planning.

1. Channel Shape. The shape of a stream channel--its width, depth, and cross-sectional appearance--is an important characteristic. The following discussion emphasizes alluvial channels or channels formed in material transported by the stream because reclaimed landscapes primarily have alluvial channels. Dunne and Leopold (1978) pointed out that a stream channel is self-formed and self-adjusting. The channel is caused and maintained by the water and debris which flows in the channel, and the channel adjusts in slope if the volume or the timing of delivery of water or debris changes. Generally, stream channels are gently rounded in cross-section and

tend to be roughly parabolic; however, trapezoidal channels with straight sloping sides are sometimes observed.

Although the channel is formed and maintained by the flow it carries, it is never large enough to carry.all discharges without overflow. In fact, overflow of the channel may be a fairly regular event. Dunne and Leopold (1978) summarize terms of importance to the study of stream channel morphology. A stream is considered flowing bankfull when it just begins to overflow its banks onto a flood plain. Dunne and Leopold (1978, p. 600) defined the flood plain as "the flat area adjoining a river channel constructed by the river in the present climate and overflowed at times of high discharge." Although river engineers define the flood plain as that part of the valley flat covered by floods, the distinction between flood plain and terrace described by Dunne and Leopold has gained increasing acceptance among geomorphologists (Williams, 1978).

Two approaches are available to determine the shape of a reclaimed channel. An engineering approach assumes that the channel slope after construction will not be altered by streamflow and uses engineering and hydraulic equations to determine channel dimensions necessary to handle a predetermined-design discharge. A geomorphic approach assumes that the stream will be able to transport bed and bank materials. Therefore, through an understanding of fluvial

processes, the drainage network and all channels are designed to be compatible with the discharge of water and sediment which must be carried.

There are hydraulic equations that determine the flow which any given channel can carry. If the design discharge is known, channel dimensions and slope can be calculated, and materials and structures necessary for erosion control can be specified. Design of channels by this engineering approach generally occurs without a geomorphic understanding of the system.

With an engineering approach, systems are designed in two ways. Erosion control structures are used to protect problem areas. Clearly, without protective measures, the channel is not stable. The other method uses no erosion control structures, and design criteria for channel dimensions do not include consideration of what would naturally occur. The engineering approach poses problems for long-term reclamation. The assumption that erosion control structures will maintain the otherwise inherently unstable channel for any period of time is dubious. Even with an optimum design, the event that exceeds the design flow has an equal probability of occurring in any given year. Furthermore, the channel may be stable if channel dimensions do not change; however, the first major flood will probably change channel dimensions and initiate erosion. If the geomorphic approach as described in this paper is used, channels and drainge patterns are

reconstructed to fit into the natural course of erosion, sedimentation, and conveyance of runoff.

Of concern in the reconstruction of stream channels is the width, depth, and cross-sectional shape of the channel to be reestablished. Thus, an understanding of the naturally observed characteristics of channel, flood plain, and terrace are important in reestablishment of valley areas. Miller and Onesti (1979) demonstrated that channel slope is influenced primarily by discharge and not by textural characteristics of channel sediment. Since naturally occurring channels construct for themselves a conduit adjusted to the water and sediment delivered to the stream, a reestablished channel in a reclamation area can be expected to do the same. To the degree that a channel is constructed to approximate the channel which existed previously, erosion and offsite sedimentation can be minimized.

2. Channel Slope. The gradient of a stream channel generally flattens downstream. The observation usually holds whether one looks at the overall change in elevation of a major river system or at an individual stream segment. Thus, the general appearance of a stream channel's longitudinal profile is concave upward. The rate of elevational change, however, varies with the characteristics of the drainage basin, and, in localized areas, streams may even increase their gradient, owing to particular site features, such as an area of

bedrock outcrop or a reach in which a tributary has entered and deposited large caliber sediment on the streambed.

Researchers agree that the general concave shape of the longitudinal profile is related to the tendency for stream discharge to increase downstream and for the particle size of the streambed and streambanks to decrease downsteam. Detailed studies made in Maryland and Virginia indicated the influence of the size of the bed material on the shape of the profile (Hack, 1957). Hack found that, for streams of equal mean annual discharge, the more quickly the bed material decreases in size downstream, the more concave is the longitudinal profile. Where bed material increases in size downstream, the profile will be less concave or may even be locally convex.

In headwater areas in the West, stream channels affected by mining usually show the greatest departure from the classic, smooth concave longitudinal profile. Leopold and Miller (1956) studied small ephemeral channels in the basins of the Rio Galisteo and the Rio Santa Fe, both tributaries to the Rio Grande in semiarid central New Mexico. These channels are characterized by a lack of influence of vegetation on channel form, by high sediment concentrations during flows, and by slow, continual downcutting, even after initial gully development. Generally, however, streamflows in the West decrease downstream due to infilitration of flow into the channel bed, in

contrast to eastern streams. Western streams show less concavity in their profiles than streams of humid areas, but the same relationships that were observed by Hack in the Eastern United States apply. Leopold and Miller found that, other factors being equal, less concave profiles are characterized by greater rates of increasing suspended sediment concentration downstream and by less rapid decrease in bed-particle size downstream.

In summary, these studies offer some qualitative observations important to reclamation of stream channels. If the average particle size of the bed material is made coarser during reclamation than existed prior to mining, the longitudinal profile will tend to steepen. If finer material is replaced, the profile will tend to flatten. If a relaimed area tends to produce more sediment, less runoff, or flow of a higher sediment concentration, the slope will also tend to steepen.

3. Channel Pattern. A channel pattern is the configuration of a stream channel as it appears in plan view. Recognized patterns include straight, meandering, and braided. Almost all stream channels are either meandering or braided, and straight reaches rarely exceed a length of 10 channel widths (Leopold and others, 1964, p. 281). No sharp distinction exists between any of these patterns, and they exist on a continuum from nearly straight streams to highly meandering. For purposes of definition, the ratio of channel length to downvalley

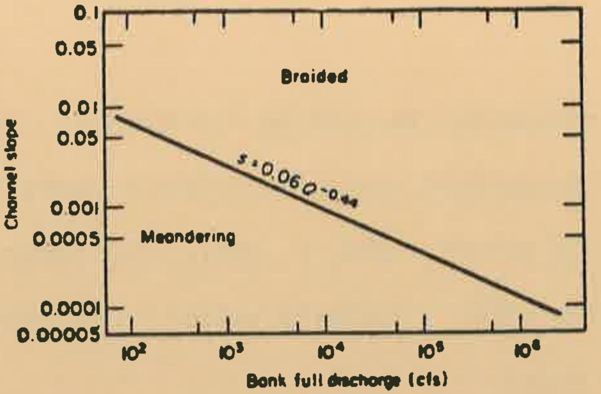
distance, called sinuosity, is used as a criterion. Various natural streams are known to exhibit sinuosity values ranging from one to four or more (Leopold and others, 1976, p. 281). For eastern Montana streamflow measuring sites, sinuosity values range from 1.0 to 3.2 (Schmidt, unpubl. data).

A meandering pattern is one which in plan view displays rounded curves of repetitive and uniform shape. Leopold and Langbein (1966) found that meander bends are neither semicircular nor sinusoidal; rather, they are of a special type called sine-generated. In a sine-generated curve, the angle of deviation from the mean downvalley direction is a sine function of the distance along the channel. The tendency to meander rather than flow straight is attributed to a stream's ability to uniformly distribute work along its course.

A braided channel pattern is one in which the stream channel separates around islands or bars. Islands may be virtually permanent entities covered with vegetation, or they may be void of vegetation and covered at high flow.

Various relationships have been developed between channel pattern and other factors. Generally, braided patterns are associated with increased sediment loads, increased bank erodibility, and increased channel slope. Meandering patterns are associated with decreased sediment loads, greater bank stability, and decreased channel slope.

A.



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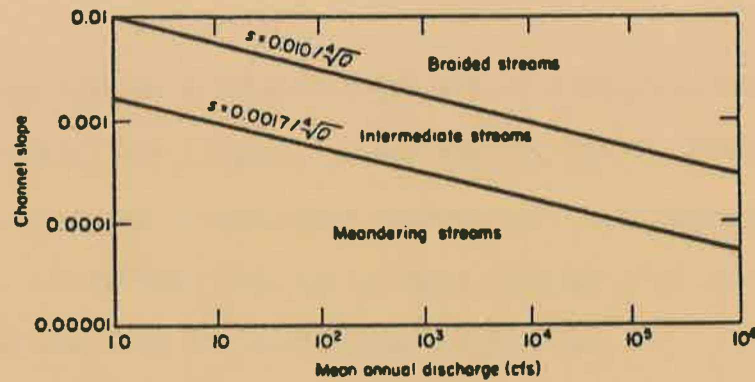

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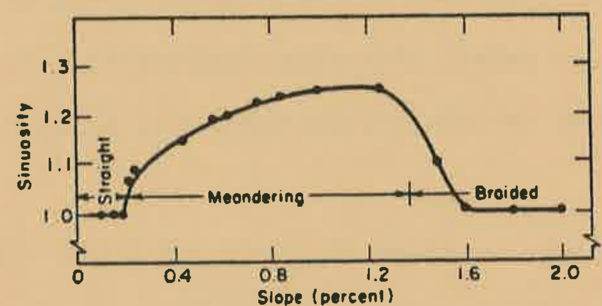

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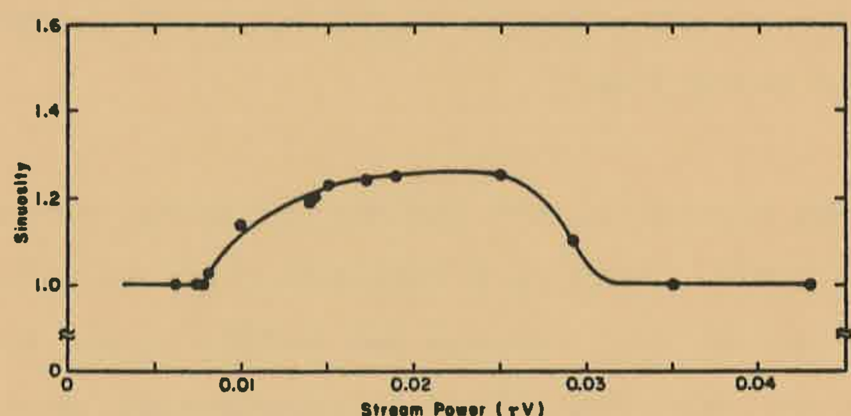


Figure E-3

Interrelationships of channel pattern and slope, discharge, sinuosity, and stream power from Schumm (1977).

In flume experiments, increased sediment load and increased slope caused different channel patterns in the manner described above (fig. E-3). In related experiments, increasing streampower is related to increasing sinuosity until a maximum is reached beyond which a braiding pattern developed. Schumm (1977) summarized these experimental findings:

> "It appears that for a given bed and bank material and discharge there is a lower threshold of stream power below which the flow is not capable of eroding the banks, and cross-channel currents are incapable of moving bed sediment to form alternate bars. There is an upper threshold of stream power, above which velocity and Froude number are high. Bank erosion is vigorous, and a wide braided channel forms with little influence of cross-channel currents. In the zone between the upper and lower thresholds meandering occurs. The banks erode but they have sufficient resistance to preserve the sinuous pattern and cross-channel currents form alternate bars which develop into point bars."

Thus, it can be seen that channel patterns will tend to change if factors affecting flow velocity change, such as discharge or channel roughness.

Studies of meandering streams indicate that meander wavelenth increases with increasing discharge and channel width and with decreasing radius of curvature. Thus, streams with larger discharge tend to meander over wider areas (fig. E- 4).

The importance of these observations and relationships for mined land reclamation planning is of most importance when channels exhibit patterns whose causative factors are near

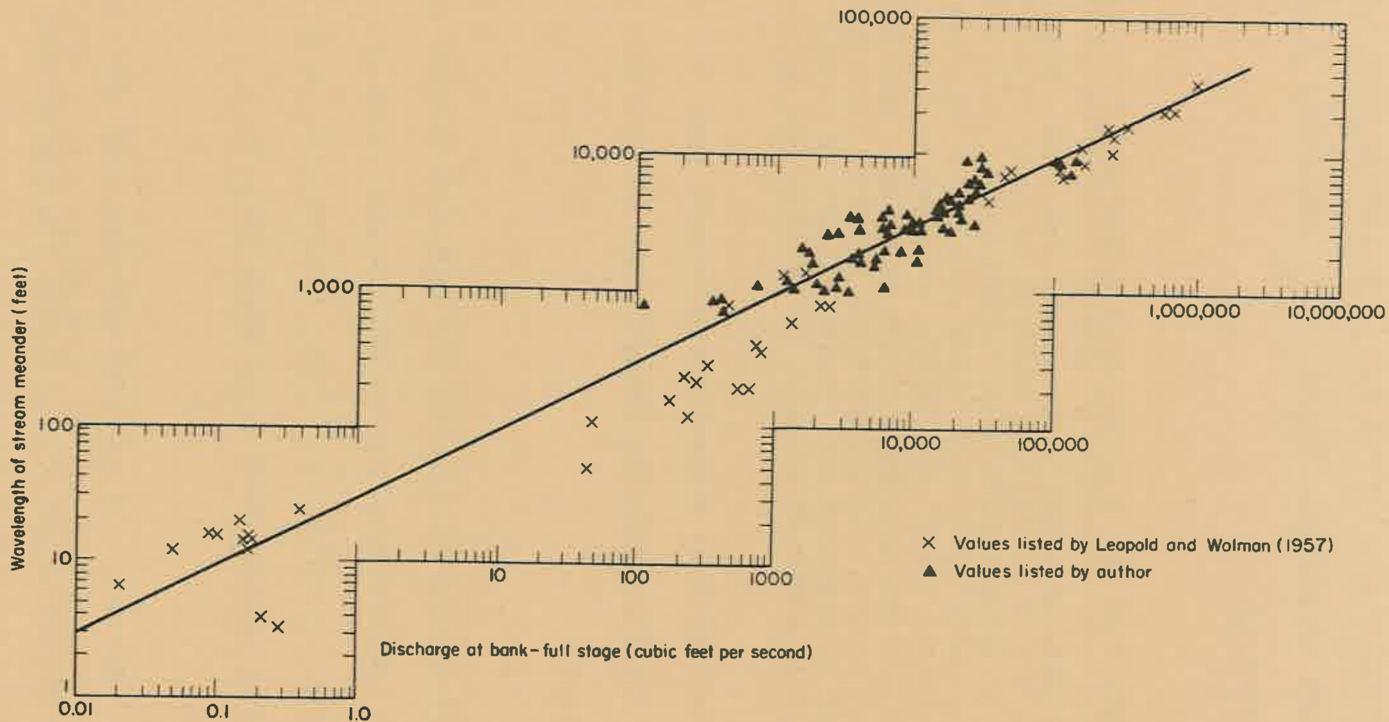


Fig. E-4 Relations between meander wavelength and bankfull discharge. (From Dury, 1964.)

threshold values. Reference to fig. 3 indicates that a small change in stream power could change a stream channel pattern from meandering to braided or vice versa. Where such changes are not consistent with channel patterns offsite, problems may develop.

4. Application to Mine Planning. The principles discussed in this appendix provide some qualitative guidance concerning the geomorphic characteristics of stream channels. Although much study has been made on the nature of stream channels, the predictive capability of the science is still relatively new. Since ephemeral streams have received the least focus of any Western stream type, the available data of relevance to Western reclamation planners is even less satisfactory.

The lack of predictive capability leads to the most basic guidance for the reconstruction of stream channels in mined areas:

(1) Where possible, drainage basin areas should be reestablished to similar sizes as the premining landscape.

Where guidance (1) can be accomplished, the following additional guidance is offered:

(2) For drainage basins reestablished to sizes similar to those that existed in the premining landscape, stream channels should be reestablished to a similar shape and slope as those that existed in the original area.

As noted previously, uniform pattern does not exist between drainage basin size and bankfull width or the size of the valley trench. Even in a small region substantial variety exists. There is some indication that small ephemeral channels are more adapted to the recent history of extreme flood events than to any regular annual flood. Thus, reestablishment of the channel size which exists in a particular reach is the safest way to ensure long-term stability.

When replication of the prexisting landscape is not feasible, the following guidance is offered:

(3) Substantial increases in drainage basin area, or changes in basin characteristics which increase unit runoff will necessitate increased channel (increased width and depth) capacity in reclamation channels.

Care should be taken when planning significant changes in the area of a stream basin. Downstream, unaffected areas will also receive increased volumes of runoff, and corresponding changes may occur in these areas. Such changes may not be tolerable.

Changes in channel slope are of substantial concern to the reclamation planner because of the increased erosive force created by steepened slopes. The following suggestion is thus made:

(4) Wherever possible, stream channel gradients should be the same or flatter than premining conditions.

Where steepened reaches are necessary, studies of the specific stream and nearby conditions should be undertaken to identify critical threshold values above which gullying of the valley floor would be initiated. Such stream gradients should be avoided.

Concepts in Reclamation Aquifer Reestablishment

Reestablishment of unconsolidated alluvial aquifers at Western coal mines is a technology in its infancy and no serious attempt has yet been tried in this area. However, in developing such plans, certain identified factors should be given consideration:

(1) The transmissivity and storage coefficient of the reeestablished aquifer. The effect of salvage and stockpiling operations on the aquifer material may result in different physical properties of the same material once it is replaced after mining. It may be more appropriate to use some other material for a reestablished aquifer.

(2) The quality of waters in a reestablished aquifer. Water generally degrades in quality when it flows in reestablished aquifers, owing to the increase in available surface area within the aquifer for chemical dissolution by water. Increases in dissolved solids in spoil water are observed at most Western mines, and the time needed to "flush out" these waters may be long enough that effects on vegetation and offsite areas should be considered.

(3) The time necessary to reestablish water levels. For example, if an aquifer will take 100 years to reestablish itself, mitigative strategies would be necessary to establish subirrigated species in a shorter timeframe.

(4) The discontinuity in transmissivities of alluvial aquifers and surrounding bedrock. In many cases, water flows in alluvial aquifers because surrounding bedrock is significantly less tranmissive than is the alluvium. In a reclamation situation, consolidated

bedrock is replaced by unconsolidated spoil, and the discontinuity in transmissive characteristics may not exist. It may be necessary to undertake special spoil handling techniques such as spoil compacting, to achieve a desired discontinuity in transmissivities.

(5) Understanding the reconstructed aquifer as a total system. As noted in the points made above, various parameters will be different in the reconstructed aquifer from those in the natural system. Therefore, the effect of changing these parameters must be viewed in terms of the entire alluvial system and whether the original functions and capabilities of the aquifer will be restored. Modeling of the proposed aquifer is suggested.

Some of these considerations are further outlined in specific mine plan discussions which follow.

Summary of Reclamation Plans

The following sections describe some examples of industry proposed relamation plans.

A. Reclamation of South Fork Spring Creek, Spring Creek Mine, Big Horn County, Montana.--A subirrigated alluvial valley floor also having the capability of being flood irrigated.

The Spring Creek mine, operated by NERCO, Inc., is located in Big Horn County, Montana, approximately 28 miles north of Sheridan, Wyoming (fig. E-5). One seam of coal, averaging 81 feet in thickness, is being mined over a permit area of 3,019 acres.

The annual average precipitation at Decker, 11 miles south of the Spring Creek mine, is 12.2 inches. Forty-five percent of the precipitation occurs between April and June, with an additional 25 percent occurring during the remainder of the growing season (July to September).

The South Fork drainage is ephemeral, with the exception of a short reach of stream within the proposed mine plan area, where perennial flow is sustained by a spring in the channel bottom. At the lower limit of mining, South Fork has a drainage area of 12.1 square miles. The lower 5 to 10 feet of alluvial fill is composed of layers of sandy gravel, interlayered with sandy silt and silt. The gravels are comprised largely of subangular to subrounded clinker and sandstone clasts. The basal gravels are predominantly overlain by silty clay (fig. E-6). A water table exists within the basal gravels throughout most of the 4.5 miles studied; however, the alluvium is drained at its lower end as it crosses clinker. In the subirrigated portion of the valley, underlying bedrock is fine grained, and seepage loss is minimal (the estimated vertical conductivity is 0.006 gpd/ft^3). Recharge occurs to the alluvial aquifer primarily from streamflow; there is no contribution of moisture from adjacent bedrock aquifers.

During 1981, the Montana Department of State Lands (MDSL, 1981a, b) determined that 90 acres of undeveloped rangeland adjacent to South

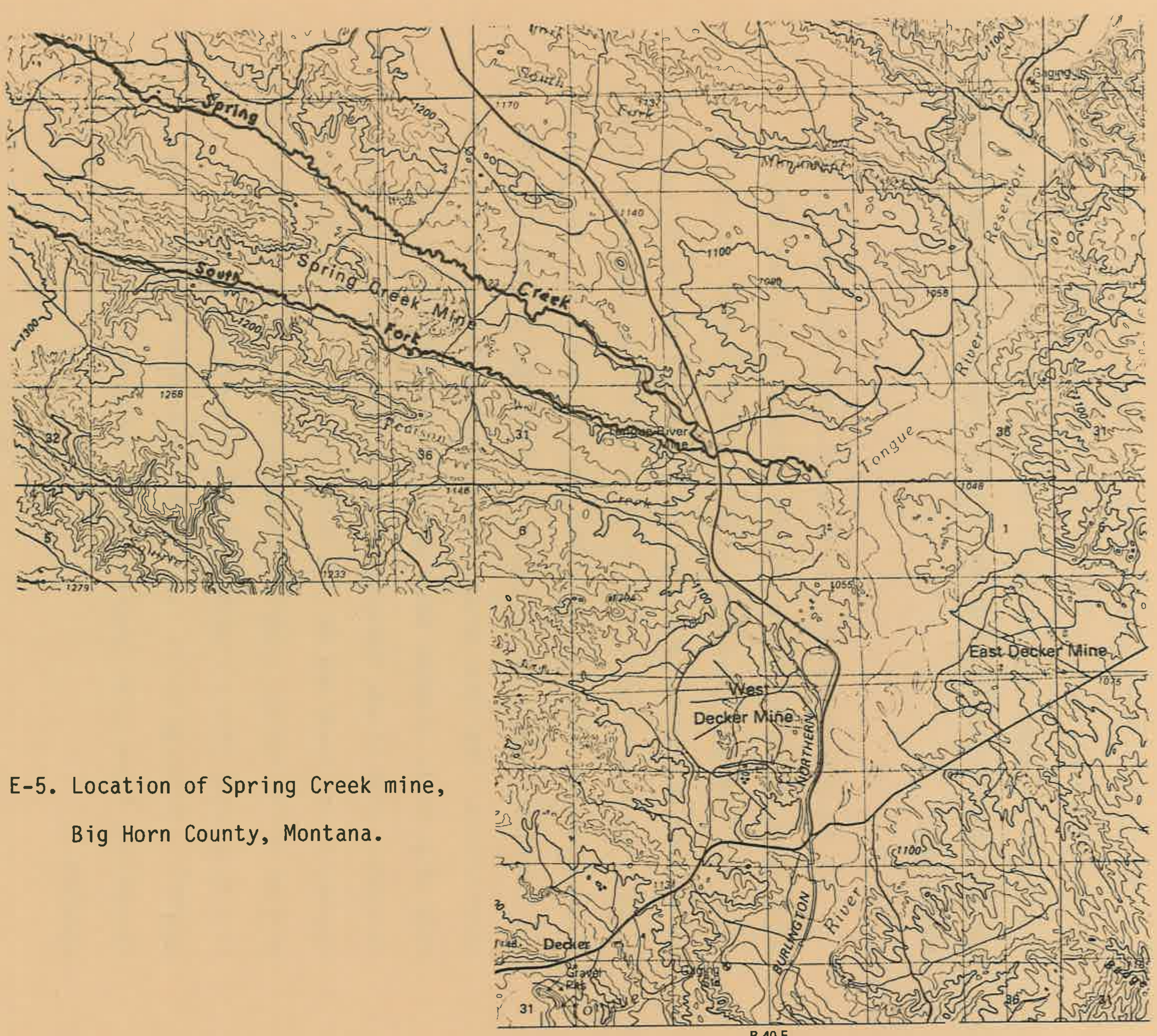
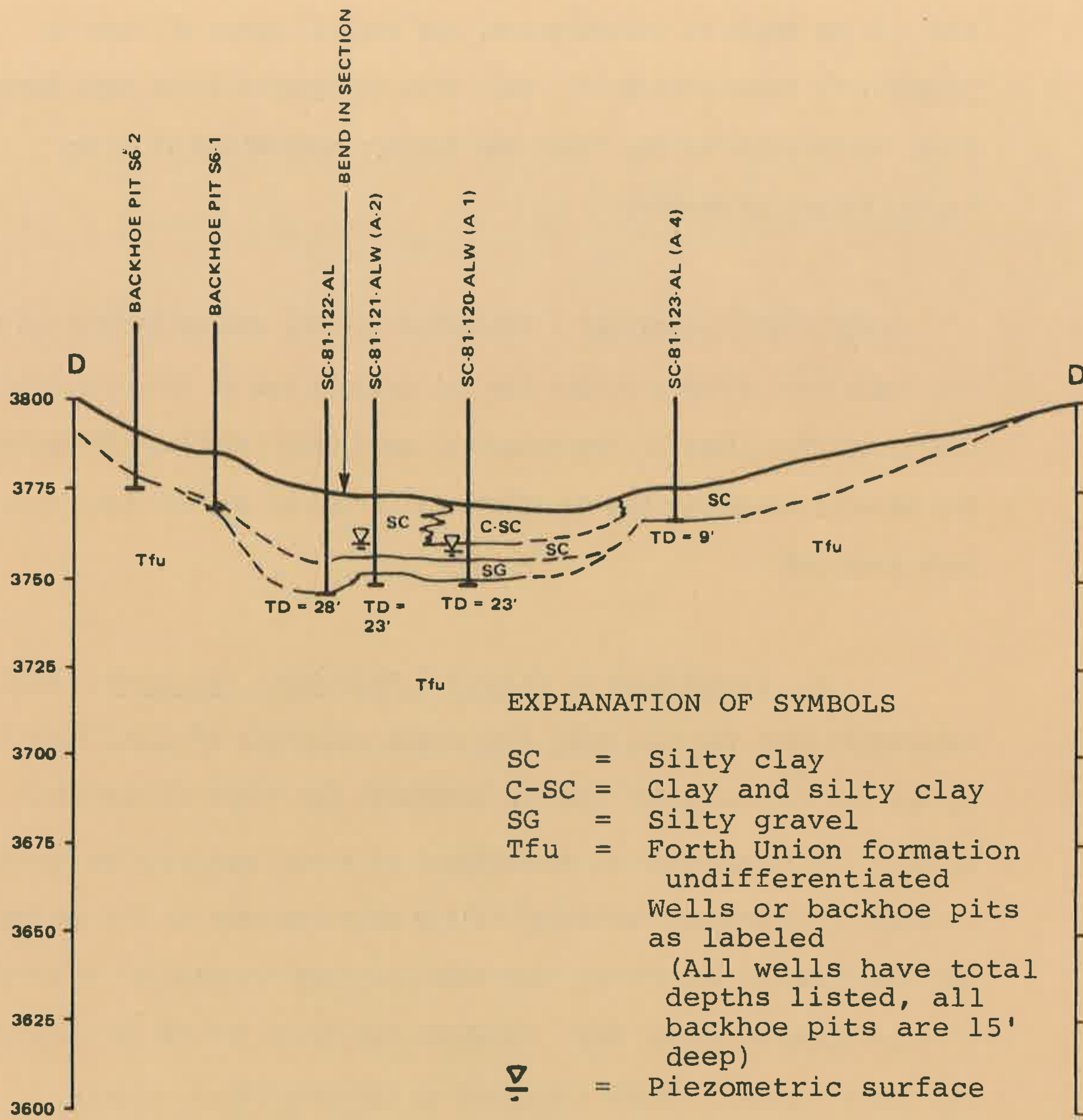


Fig. E-5. Location of Spring Creek mine, Big Horn County, Montana.

Fork Spring Creek is subirrigated, and that 87 acres of land is potentially flood irrigable. MDSL thus designated South Fork Spring Creek an alluvial valley floor and further determined it to be insignificant to farming.

NERCO (1981) submitted a conceptual mining and reclamation plan for South Fork which provides for the restoration of the essential hydrologic functions of subirrigation and potential flood irrigation. Operational plans for how to accomplish each reclamation task have not been proposed.

1. Restoration of Essential Hydrologic Functions. MDSL determined that the essential hydrologic functions of South Fork valley are subirrigation and the potential for flood irrigation. NERCO's (1981) approach to development of a reclamation plan involved analogy. The company collected fairly detailed data on the geology and hydrology of the valley, and then proposed re-creation of those natural characteristics most important for flood irrigation potential and subirrigation. NERCO attempted to identify those natural characteristics which could be re-created during reclamation and proposed substitutes for those which could not be re-created. For example, NERCO identified those portions of the stream channel which could be restored (stream flowing in unconsolidated alluvium) and those which could not (stream flowing over bedrock). A reclamation plan was then proposed (using spoils and selectively salvaged



HORIZONTAL SCALE: 1" = 400'
VERTICAL EXAGGERATION = 8X

Fig. E-6.

SOUTH FORK SPRING CREEK
CROSS SECTION D-D'

alluvium) which simulated the natural reach in unconsolidated alluvium. NERCO's reclamation plan identifies four elements which are important in restoring the essential hydrologic functions:

(1) Restoration of the valley bottom topography.

(2) Reconstruction of the stream channel and flood plain.

(3) Restoration of an alluvial aquifer and the associated subirrigation function.

(4) Replacement of suitable soils and establishment of vegetation.

a. Flood Irrigation Capability

(1) South Fork valley restoration.--In order for the potential for flood irrigation to be restored to South Fork Spring Creek valley, NERCO designed a stable landscape that could accommodate flood irrigation agricultural activities in a way no less restrictive than the present landscape. NERCO developed the following goals:

(1) Restore landforms similar to the original topography.

(2) Increase the agricultural utility of the valley by broadening and consolidating flat-lying terrace areas.

(3) Minimize erosion, by creating no slope steeper than 0.20 (5h:1v) unless dictated by channel stability constraints.

(4) Allow the stream channel to incise no deeper than the current incision.

Thus, NERCO's goal was the re-creation of the existing physical attributes of the valley. The company assumed that this approach would reestablish a potential for irrigation similar to that which presently exists. The mining and reclamation plan calls for creating an average downvalley slope of 0.0142 (75 feet/mile). The existing valley, over the same reach, has an average slope of 0.0139 (74

feet/mile). The range in reclamation valley slope is from 0.0161 (85 feet/mile) to 0.0123 (65 feet/mile) (fig. E-11). The valley width ranges from 550 feet to more than 800 feet. Subtle variations in the downvalley slope and valley width are incorporated into the South Fork restoration plan to blend with surrounding topography, to provide diversity, and most importantly, to ensure subirrigation of surface vegetation. (See later discussion.)

The reclaimed valley would have approximately twice the amount of flat-lying terrace landform than currently exists. The cross-section design of the valley varies from flat-lying to gently sloping (up to 0.020), with a valley trench approximately 3 to 6 feet below the valley surface. NERCO distinguishes between the valley trench and the active channel. As noted below, field observations were made of an active channel at 1.5 feet within a larger trench, which is up to 6 feet below the adjoining terraces. The combination of wide, essentially flat valley landforms, as much as 6 feet above the reclaimed channel, will allow the construction of diversion ditches from the channel downstream to those flat areas or the construction of spreader dikes.

(2) South Fork channel reconstruction.--The basic assumption made in plan development was that a description of the existing characteristics of the channel provides the most useful starting point for developing a channel reclamation plan. In

addition, the plan assumed that water and sediment delivery to the stream will remain the same following reclamation. This is a reasonable assumption, inasmuch as less than 15 percent of South Fork Spring Creek basin is to be disturbed by mining, according to known mine plans. A determination of the premining bed and bank material texture was made and compared to the expected values for the reclaimed topography. The conclusion was that the relamation bed and bank material texture would approximate that of the midvalley portion of the present South Fork. The upper part of the valley contains bedrock outcrops and armoring that will not be restored in the postmining landscape.

Channel slopes were evaluated for the entire drainage basin (scale 1:24,000), for the entire reach to be disturbed (1:4,800), and at seven sites where detailed field surveys were made (1:480). NERCO observed that, within the reach to be disturbed, the profile was steep at first, flattened, and then steepened at the lower end. When measured in the field, the steepest channel reaches were 0.014 (74 feet/mile), whereas the flatter central area of the valley had gradients of 0.04 to 0.005 (21 to 26 feet/mile). Steeper reaches were found in areas of bedrock outcrops or gravel armoring of the bed. Because mining will eliminate bedrock and gravel armoring, reclamation stream gradients were established to be the same as the flattest natural reaches.

The cross-sectional configuration of the reclaimed channel for South Fork approximates the active channel dimensions measured in the field. The active channel was approximately 4 feet wide, 1.5 to 2 feet deep, and 3 to 12 feet below the adjacent terrace surface (fig. E-7). The reclaimed active channel was designed as a trapezoidal channel with a 4-foot bottom width with 0.33 (3h:1v) side walls. As noted above, the channel varies between 3 to 6 feet below the valley. Equipment limitations prevent exact duplication of the natural channel; however, NERCO estimates that sediment deposition within the re-created trench will ultimately create an active channel with similar dimensions to existing conditions (fig. E-8). Because the channel slope to be reestablished is slightly flatter than the flattest measured slope, this approach does not seem unreasonable.

The most frequent channel pattern observed for South Fork in its alluvial reaches has a wavelenth of 120 feet and an amplitude of 45 feet. The reclaimed channel was designed using these dimensions of wavelenth and amplitude. The sinuosity of the postmining channel was increased to obtain the flatter, less erosive channel gradient. The maximum sinuosity of the restored channel was set at 2.4 compared with a maximum of 2.1 in the existing channel.

NERCO evaluated its design for channel reconstruction in two ways. First, the drainage design was checked to see how different reaches would respond under various recurrence-interval flow events

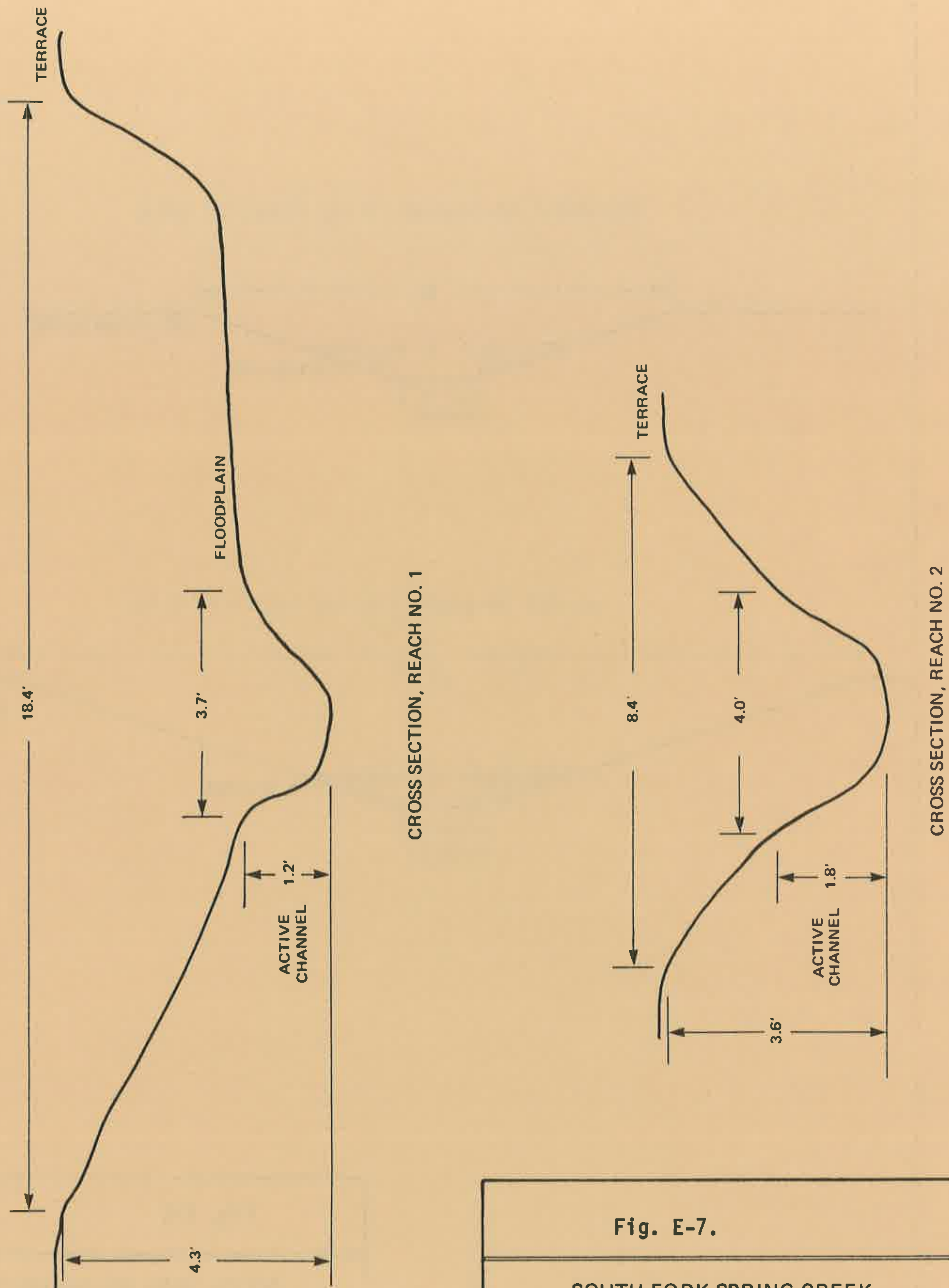


Fig. E-7.

SOUTH FORK SPRING CREEK
AVERAGE CROSS SECTIONS
DETAIL REACHES NOS. 1 & 2
VIEW UPSTREAM

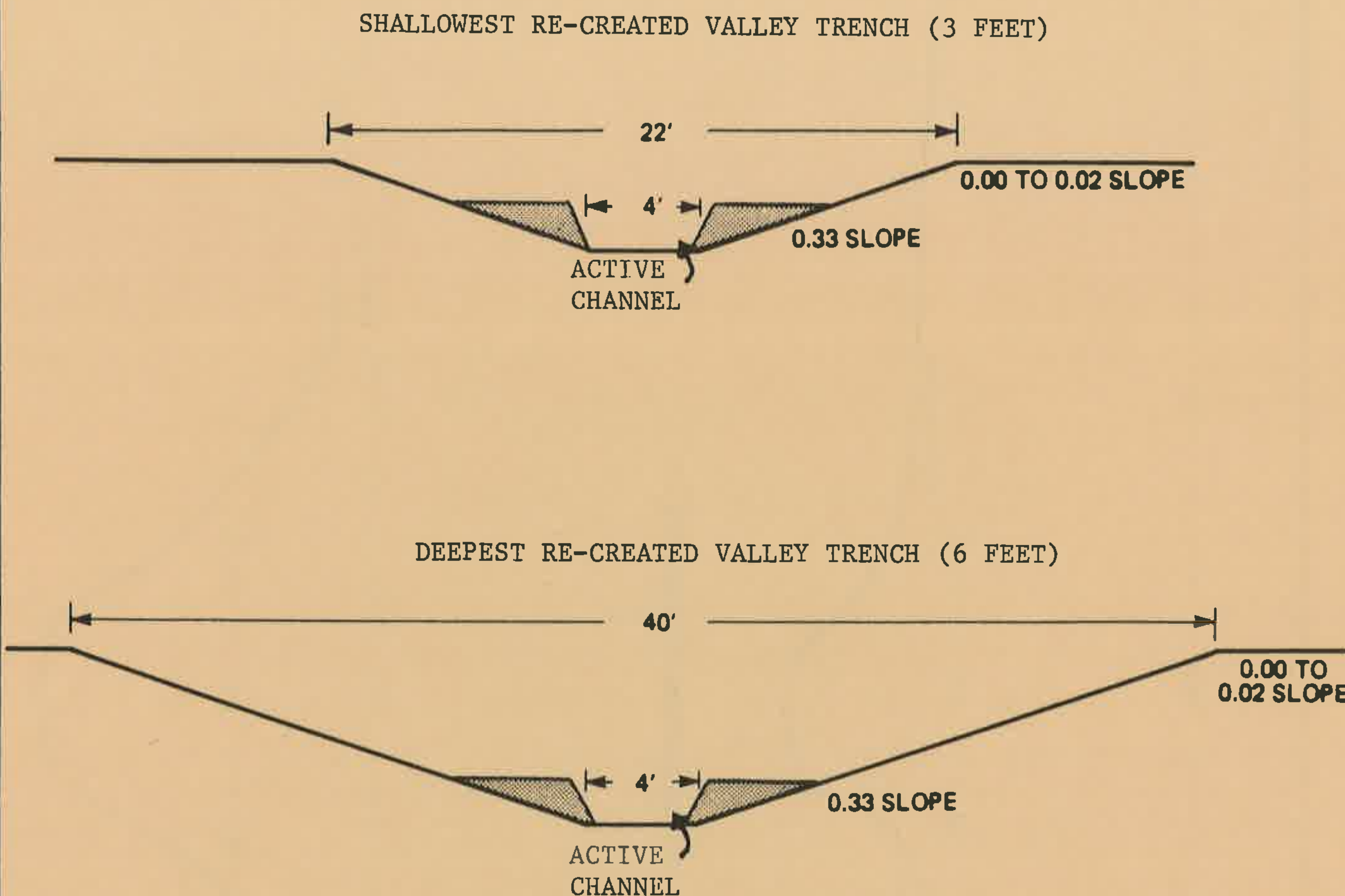


Fig. E-8.

SOUTH FORK SPRING CREEK
PROPOSED CHANNEL CROSS-SECTIONS
AFTER SEDIMENT DEPOSITION

(table E-1). Flood discharge was determined using techniques of Johnson and Omang (1976), and stage during floods was determined using U.S. Army Corps of Engineers (1979) techniques. Roughness of the reclaimed terrace surface (which would be inundated by floods) was assumed to be slightly less than that for existing topography. More specifically, two sections of restored stream and flood plain were evaluated. These included restored channel reaches with the deepest (6 feet) and the shallowest (3 to 4 feet) configurations. This analysis showed that the shallow valley trench is capable of containing floods up to a 5-year recurrence interval, whereas great magnitude events would spill overbank. In stream reaches 6 feet deep, floods with recurrence intervals up to 100 years are contained within the valley trench. NERCO concludes that the reconstructed valley will be influenced by flooding in a similar manner to the existing South Fork Spring Creek valley.

The erosional stability of the drainage network was also evaluated. Velocities under flood conditions were predicted (U.S. Army Corps of Engineers, 1979) to be similar to the undisturbed channel (table E-1). Shear stress (Leopold and others, 1964, p. 157) was calculated for both the reclaimed and natural drainage systems. The results of the analysis found the reclaimed system to be comparable to the natural drainage system existing in South Fork Spring Creek valley.

TABLE E-1

HYDRAULIC CHARACTERISTICS SOUTH FORK SPRING CREEK

Flood frequency (Yrs)	Discharge (cfs)	Depth (ft)	Area (ft^2)	Top width (ft)	Velocity Avg. (fps)	Velocity Overbank (fps)	Velocity Channel (fps)
A. Three-Foot Deep Reconstructed Trench							
2	32	1.5	13.0	13.1	2.46	0	2.47
4	90	2.5	27.9	18.7	3.23	0	3.23
10	150	3.1	57.1	553	2.63	0.26	3.66
25	250	3.2	143	569	1.79	0.83	3.88
50	340	3.3	193	577	1.76	1.07	4.03
100	450	3.4	245	586	1.84	1.29	4.14
B. Six-Foot Deep Reconstructed Trench							
2	32	1.5	13.0	13.1	2.46	0	2.47
5	90	2.5	27.9	18.7	3.23	0	3.23
10	150	3.1	40.7	22.5	3.69	0	3.69
25	250	3.8	59.7	27.1	4.19	0	4.19
50	340	4.4	74.7	30.2	4.55	0	4.55
100	450	4.9	92.3	33.5	4.88	0	4.87

b. Subirrigation

(1) Restoration of alluvial aquifer. The subirrigated portion of South Fork Spring Creek valley was evaluated by NERCO in order to understand the processes which make water available to plants throughout the summer months. Four critical characteristics of the valley were identified, as follows:

1. Ability to store sufficient ground water in the valley-fill materials such that water is available to the system throughout the growing season.
2. Ability to transmit water from the gravel aquifer upward to the subsoils.
3. Existence of a high water table in the subirrigated area throughout the growing season.
4. Holding of ground water within the valley-fill aquifer system (or not permitting significant leakage).

Within the mine plan area, ground water in the South Fork Spring Creek valley comes from streamflow losses and from upvalley alluvial ground water, not from a more regional bedrock ground-water system in the area of the mine.

Field investigations and subsequent calculations by NERCO estimated that 34 acre-feet of active seasonal ground-water storage is available, primarily from the portion of the valley above the subirrigated area, also proposed for mining. NERCO termed this area the "storage area" because ground water is stored in the area during

high-flow periods and released at low-water times, ensuring constant water availability to the subirrigated area. The reconstructed aquifer system in the reclamation plan provided 72 acre-feet of storage upgradient from the subirrigated area in order to provide greater assurance of subirrigation.

The South Fork Spring Creek alluvial aquifer is currently transmitting approximately 64 acre-feet of water per growing season through the subirrigated portion of the valley. The reclaimed aquifer was designated to transmit 1 acre-foot of water per acre of restored subirrigated area during the growing season. This will provide 90 acre-feet of water during the growing season, or a 38-percent greater flow capacity than the existing system.

The proposed alluvial aquifer is to be 550 feet wide to allow for the most rapid mining sequence. This width is equal to the width of two minecuts. The specifications NERCO proposes for the alluvial aquifer involve selectively salvaging and replacing alluvial gravels and adding clinker gravels. Addition of clinker gravels is necessitated because excavation, mixing, and redumping of the natural stream gravels is predicted to result in destruction of structure and in a probable increase in the density of the gravel. These changes will considerably reduce the hydraulic conductivity of the material from 1,750 gpd/ft^2 to an estimated 200 gpd/ft^2. Therefore, a high conductivity layer of clinker (3,000 gpd/ft^2) has been designed into

the restored aquifer system. NERCO acknowledges that field testing of the hydraulic characteristics of the clinker and rehandled alluvial material will be necessary to arrive at a final design for the alluvial aquifer.

The topographic gradient for the restored alluvial aquifer is based on the gradient of the restored stream system described earlier. The hydraulic gradient of the water-table aquifer is expected to be the same as the topographic slope along the valley. As noted, an upstream area of the re-created valley is designed to have a high transmissivity in order to:

1. Readily receive all percolation.
2. Quickly convey all recharge to the downstream reconstructed subirrigated area.
3. Serve as a storage zone for alluvial ground water during periods when water is not being withdrawn from the aquifer by vegetation.

To achieve these characteristics a basal layer of clinker is used to allow direct flow to the subirrigated area (fig. E-9). An upper layer of replaced alluvial gravels serves as storage.

A lower reach of restored alluvial aquifer (fig. E-10) below the subirrigated area is intended to be the subirrigated area. According to recharge and flow calculations made by NERCO, the lower aquifer should always be saturated in normal water years The purpose of

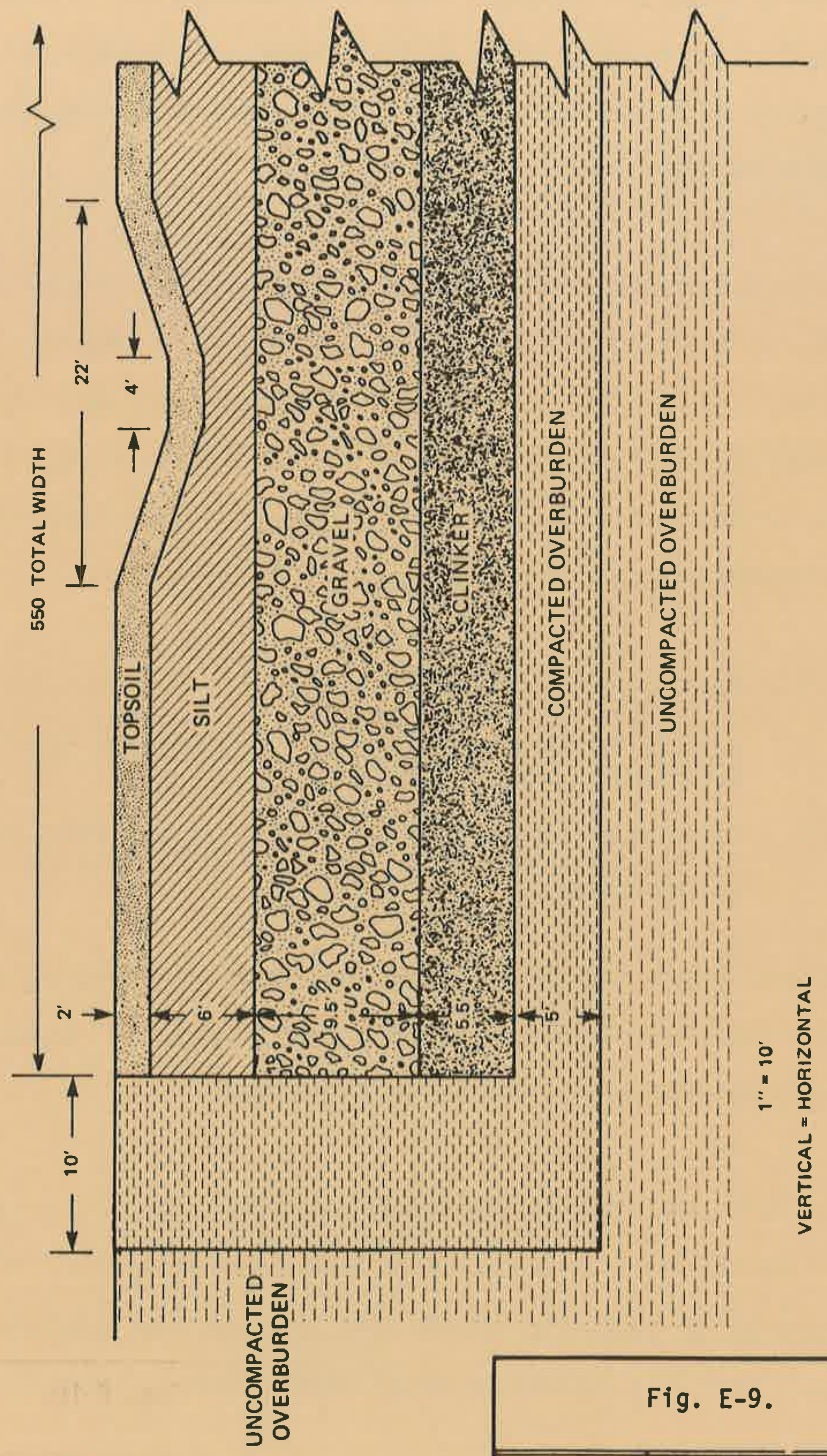


Fig. E-9.

CROSS SECTION IN UPSTREAM STORAGE AREA

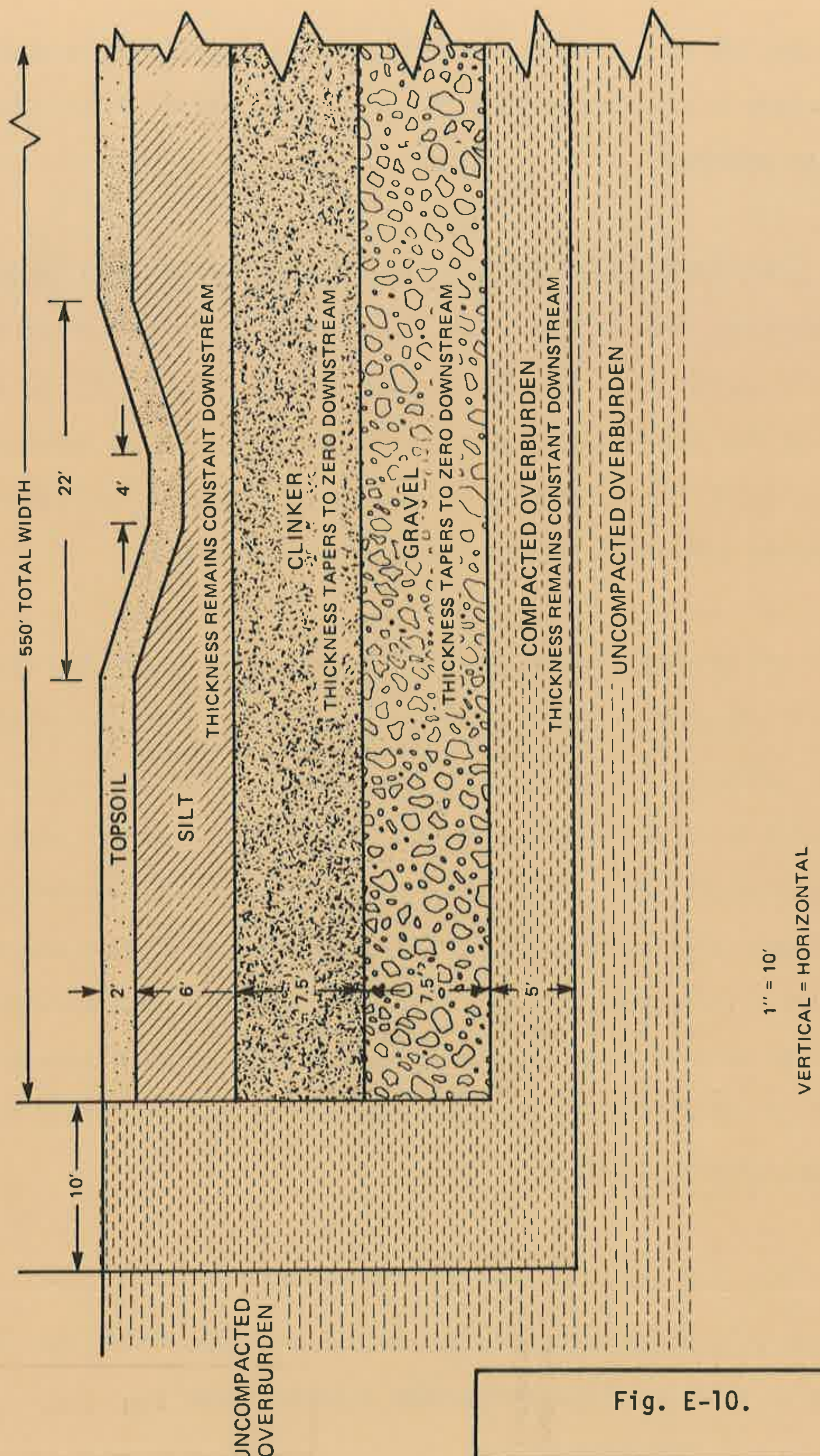


Fig. E-10.

CROSS SECTION IN SUBIRRIGATED AREA

placing the more permeable scoria gravel on top of the rehandled alluvium is to cause a small change in water level for any change in water quantity.

The thickness of the restored alluvial aquifer will taper downstream, from 15 feet thick in the upper 2,530 feet of stream and at the upper end of the subirrigated area to 0 feet thick at the lower end of the subirrigated area (an additional 7,130 feet downstream (fig. E-11). This decrease in aquifer thickness is intended to assure complete saturation through the subirrigation reach.

The alluvial aquifer will be underlain by a compacted layer of spoil. Results of standard laboratory tests (NERCO, 1981) indicated that extremely low hydraulic conductivities can be achieved through compaction of overburden materials to provide a suitable barrier to ground-water flow. Field testing will be used to determine which equipment will achieve the desired spoil density beneath the stream valley. Therefore, the only discharge from the restored alluvial aquifer will be minor seepage losses and vegetation withdrawals. Five feet of salvaged silty clay alluvium will be replaced above the gravel/clinker aquifer.

The pore volume of the alluvial aquifer was calculated, and when compared to ground-water inflow rates, it was estimated that it would take 10 years to fill the restored alluvial zone.

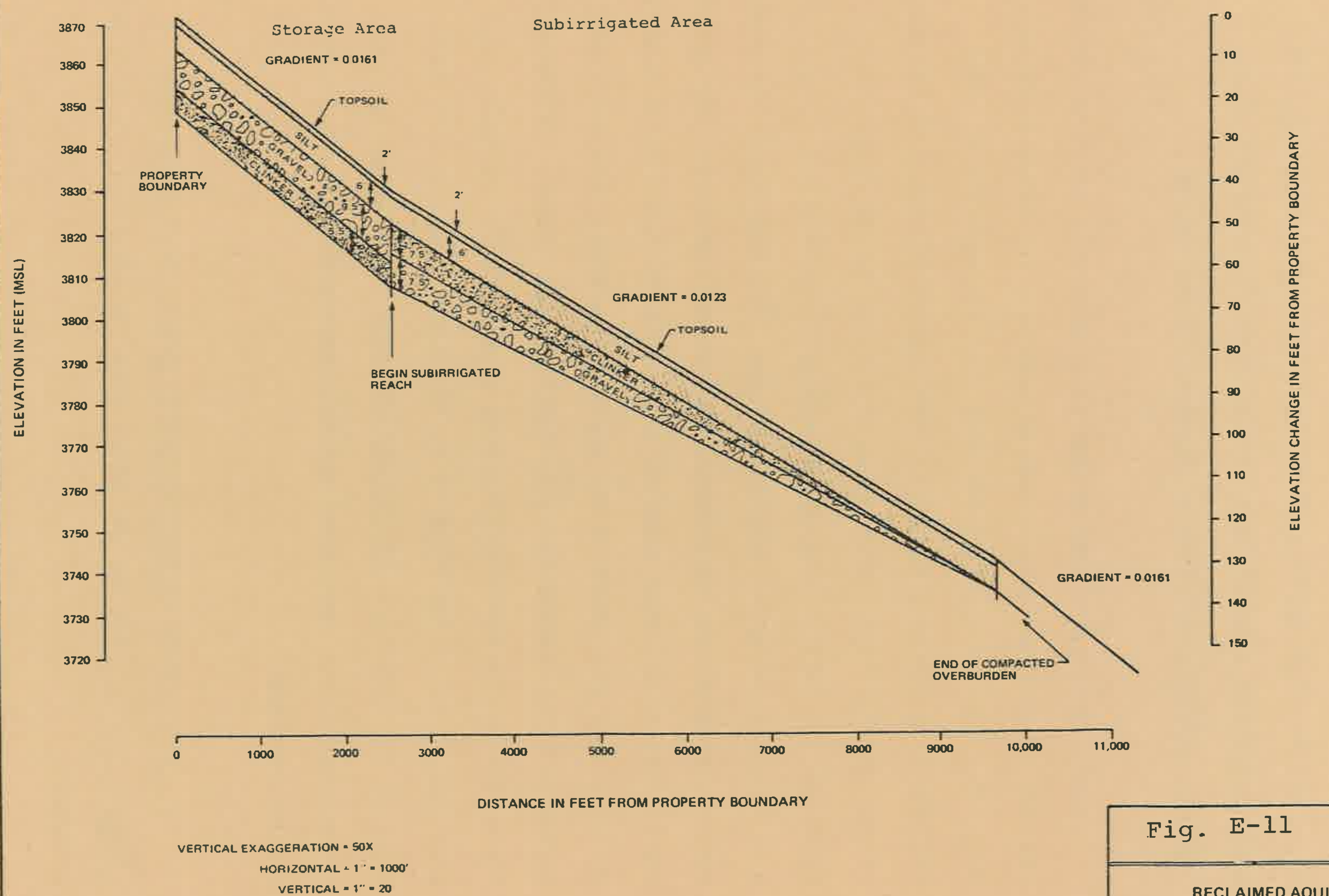


Fig. E-11

RECLAIMED AQUIFER LONGITUDINAL PROFILE

A limited water-quality evaluation of the postmining alluvial aquifer predicted quality to be suitable for subirrigation on the basis of the water quality of the upstream undisturbed alluvial aquifer and the apparent lack of contaminating materials (i.e., topsoil, clinker, and alluvial gravels) in the system.

NERCO anticipated that ground settlement will occur within the 155 feet of replaced spoils, borrow material, and alluvial material. Uniaxial compression tests indicated that the majority of total settlement is expected to result from compaction caused by the weight of the material itself and, thus, will occur during backfilling. Following the initial grading and compaction of the spoil, subsidence will be monitored until settling ceases. Once settlement has stopped, work on constructing the alluvial aquifer will proceed. The weight of the 15 feet of alluvial material is expected to cause 1-1/2 to 2 feet of additional settlement in the spoils. Therefore, the spoil must be overbuilt to compensate for this addtional settlement. Settlement of the spoils due to hydroconsolidation as the spoils resaturate was predicted to be an additional 5 to 10 percent. Because the spoils are expected to resaturate very slowly and only in the lower 50 feet, hydroconsolidation settlement was not considered to be an important problem by NERCO.

B. Reclamation of East Fork Coal Creek, Coal Creek Mine, Campbell County, Wyoming.--A valley with the capability to be flood irrigated.

The Coal Creek mine is located in Campbell County, Wyoming (fig. E-12). The climate at the mine is semiarid, with approximately 12.3 inches of precipitation annually. About 79 percent (or 9.8 inches) of the annual precipitation is received during the growing season (April-September). The major drainage extending through the minesite is East Fork Coal Creek, an ephemeral stream with a drainage area of 18.2 square miles. Other tributaries to Coal Creek will also be affected by mining to a limited extent. Topography in the area consists of gently rolling hills with wide valleys and frequent, deeply incised drainage channels.

Based on the latest assessment by the Wyoming Department of Environmental Quality, Land Quality Division (WDEQ-LQD, 1981), East Fork Coal Creek above its confluence with the tributary drainage in sec. 33, T 46 N., R. 70 W., is an alluvial valley floor. Other alluvial valley floors have also been designated in the permit area. A formal assessment of significance to farming of the alluvial valley floors has not yet been made. The majority of the alluvial valley floor areas within the proposed permit area are undeveloped rangelands.

WDEQ-LQD has reserved final identification of the essential hydrologic functions of East Fork Coal Creek valley pending the outcome of additional studies currently being conducted by ARCO Coal Company. However, these functions probably are the potential for flood irrigation, based on historic use of water spreading on

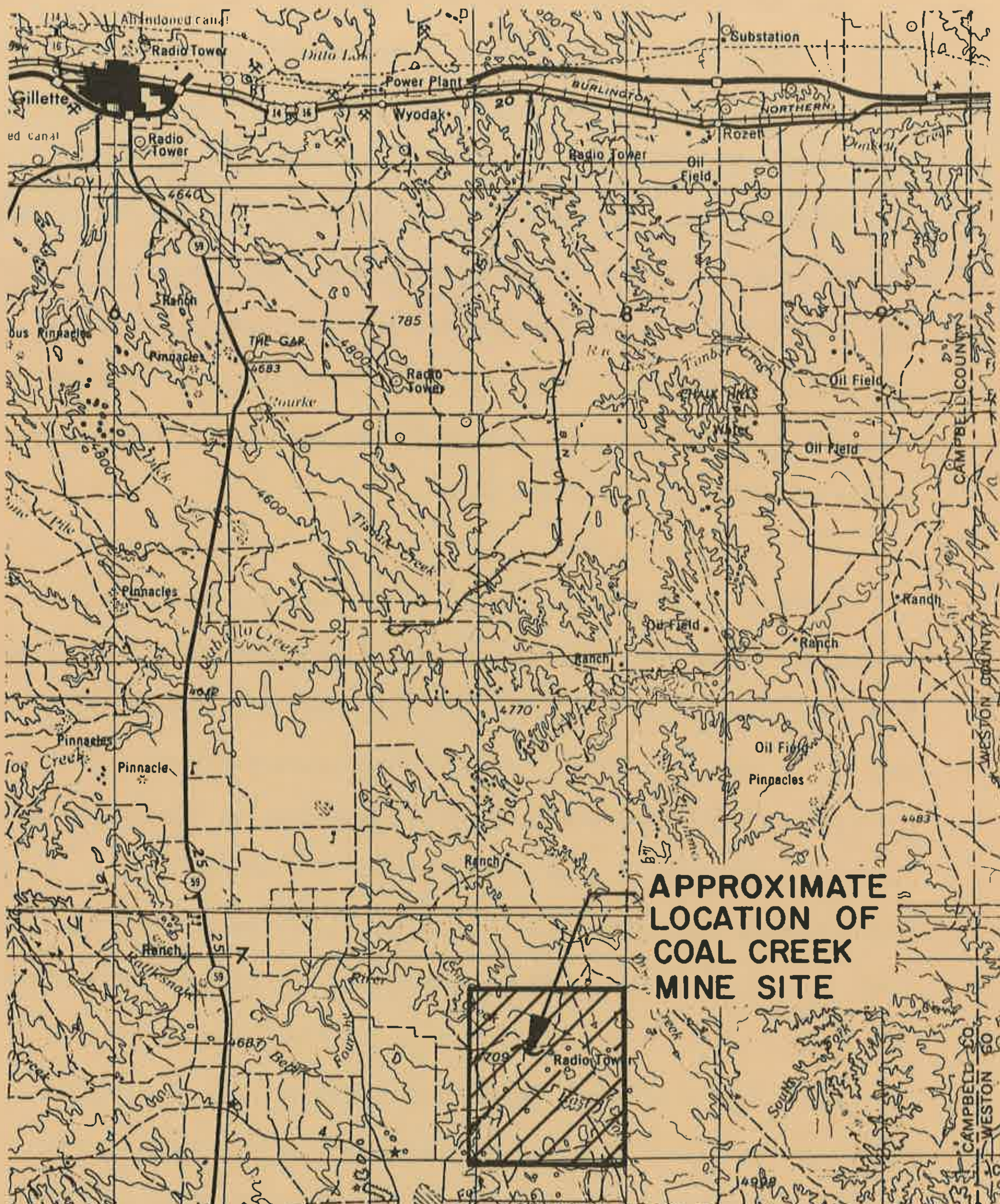


Fig. E-12. Location of Coal Creek mine, Campbell County, Wyoming.

tributary drainages and the presence of limited subirrigation and an alluvial aquifer. Backhoe pits and associated investigations of rooting depth, mottling, and soil moisture profiles have indicated that limited subirrigation occurs along East Fork Coal Creek on the lower terrace.

1. Restoration of Flood Irrigation Capability. The mining and reclamation plan for the Coal Creek mine (ARCO, 1981) does not provide for the restoration of subirrigation along East Fork Coal Creek. The subirrigation issue will soon be addressed by WDEQ-LQD, pending the outcome of additional hydrologic studies.

East Fork Coal Creek is the primary drainage to be disturbed by mining, and the design of the postmining valley restores the potential for flood irrigation in the valley. Basically, the design attempts to restore a stable postmining stream channel and valley configuration, thereby providing the potential for flood irrigation.

Evaluations of the channel characteristics of East Fork Coal Creek indicate that the creek is currently undergoing significant channel erosion and degradation. Indications of channel degradation include severe headcuts and a low width-to-depth ratio for the channel. The high silt/clay content of the channel banks resists caving as the channel downcuts, thus maintaining a deep, narrow channel. Reproducing this highly erosive channel configuration would

be contrary to general reclamation objectives. Therefore, the reclamation plan attempts to design a new stream/valley system with greater stability than the existing drainage basin has.

The hydrologic and geomorphic design considerations used by ARCO, and the elements of their restoration plan for the East Fork Coal Creek valley are presented in the following sections.

(a) Design considerations.--Two principal hydrologic parameters were used designing the postmining valley topography:

1. The frequent, 1- to 2-year recurrence interval flow event. (This event was considered to be approximately bankfull flow and was used to size a "pilot" channel.)

2. The 100-year flood was considered the primary design consideration for the flood plain configuration.

The mining and reclamation plan considered the following three principal factors to be significant in the development of the current stream channel and valley morphology of East Fork Coal Creek:

1. Local and regional geology.
2. Stream gradient.
3. Stream channel bed and bank materials.

The stream gradient and bed and bank materials were considered to be the most important factors in determining the design of a stable drainage system. The channel gradient was considered such a

dominating factor that the existing channel gradient was considered an unchangeable design element.

(b) Restoration plan.--The restoration of channel gradients was accomplished using a series of meanders with an alternating system of pools and riffles (fig. IV.I-1, Coal Creek Mine Permit Application, ARCO, 1981). The restored drainage system will imitate the existing channel configuration by incorporating a smaller pilot channel designed to pass the frequent bankfull flow event and a larger flood channel designed to pass large flood events.

The pilot channel and flood channel have been designed to allow floods to spill overbank flow out of the pilot channel, thus reducing the erosive velocities below what is presently occurring in the natural narrow, deep channel. In general, narrow, deep channels provide less friction and, therefore, higher velocities. Conversely, shallow, wide channels have greater areas exposed to the stream, resulting in more resistance to flow and, thus, lower velocities.

(1) Pilot channel.--The pilot channel (or active channel equivalent) was designed to convey the frequent, 1- to 2-year flow events. The Craig-Rankl method (1977) was utilized to determine the size of this flood event.

The width-to-depth ratio of the channel was determined from empirical relationships in Schumm (1977), which resulted in a 6:1 width-to-depth ratio for the 20-percent clay-silt bed and bank material specific to the minesite. The meander wavelenth for East Fork Coal Creek drainage system was determined from a modification of equations presented by Dury (1976) and Leopold and Wolman (1957).

The pool/riffle spacing along the reclaimed pilot channel was established to be approximately six times the channel width (as discussed by Keller, 1975). These pools and riffles will provide added channel roughness and will extend the percolation time for flood waters. This addition of moisture to the valley fill may be utilized by vegetation along the channel bottom. Adjustments in all the channel parameters are expected over time as the pilot channel "fine tunes" itself.

(2) Flood channel.--The reclaimed flood channel (lower terrace or flood plain equivalent) is expected to merge smoothly with the upstream undisturbed stream system and will contain the pilot channel.

The Coal Creek mining and reclamation plan specifies that valley fill materials of comparable quality to premining soils be placed in the valley bottom to a depth of at least 8 feet in order to provide a suitable root zone and to prevent floodflows from scouring the

underlying, poorer quality spoil. The valley fill materials at the Coal Creek site are also expected to be of comparable texture to valley fill materials upstream so there will be a match with the adjacent undisturbed stream system.

The size of the flood channel for East Fork Coal Creek was determined by comparing the velocities of the predicted 100-year floodflow with threshold erosional transport velocities determined from the texture of the valley bottom materials (Chow, 1959). The channel was widened until the flow velocities for the 100-year flood were reduced below the threshold erosional point. The slope of the valley bottom, both toward and parallel to the stream channel, was designed at 0.3 percent to provide good drainage.

(3) Additional reclamation concepts.--The following list provides a summary of additional reclamation concepts utilized in the East Fork Coal Creek drainage restoration plan:

1. The restored channel will be graded to blend smoothly with the adjacent undisturbed topography above and below the minesite.

2. The pilot channel has a trapezoidal configuration; however, the erosional processes are expected to modify the channel configuration to the more natural asymmetrical shape of natural channels with minimal sediment movement.

3. The restored valley fill was specified to have a suitable cation exchange capacity, sodium adsorption ratio, and salt content for the postmining land use.

4. A temporary clinker liner (-3 inches) was specified for 250 feet on either side of the junction of the reclaimed drainage system with the undisturbed stream. The clinker is to provide temporary stabilization for the stream through the transition zone.

5. Appropriate vegetation seeding suitable for bottomlands will be established along the flood channel (flood plain and lower terrace equivalent).

C. Reclamation of Caballo Creek, Belle Ayr Mine, Campbell County, Wyoming.--A subirrigated and potentially flood irrigated alluvial valley floor.*

The Belle Ayr mine is operated by AMAX Coal Company and is located approximately 15 miles south of Gillette, Wyoming, in Campbell County (fig. E-13). The mine has been operating since 1973. The coal (Wyodak seam) is extracted by the truck and shovel method.

Mean annual precipitation in the area is estimated to be 15.6 inches per year. Caballo Creek, an intermittent tributary to the Belle Fourche River, flows from west to east through the middle of the permit area. Tributaries north of Caballo Creek in the permit area include Duck Nest Creek and Tisdale Creek. Tributaries south of the creek include Clabaugh, Demott, and Les Draws. All these drainages

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*Although no alluvial valley floors have been determined to exist in the area directly affected by the Belle Ayr mine, the following discussion describes a ground-water and surface-water restoration plan which could be applicable in places where restoration of the essential hydrologic functions of an alluvial valley floor would be required.

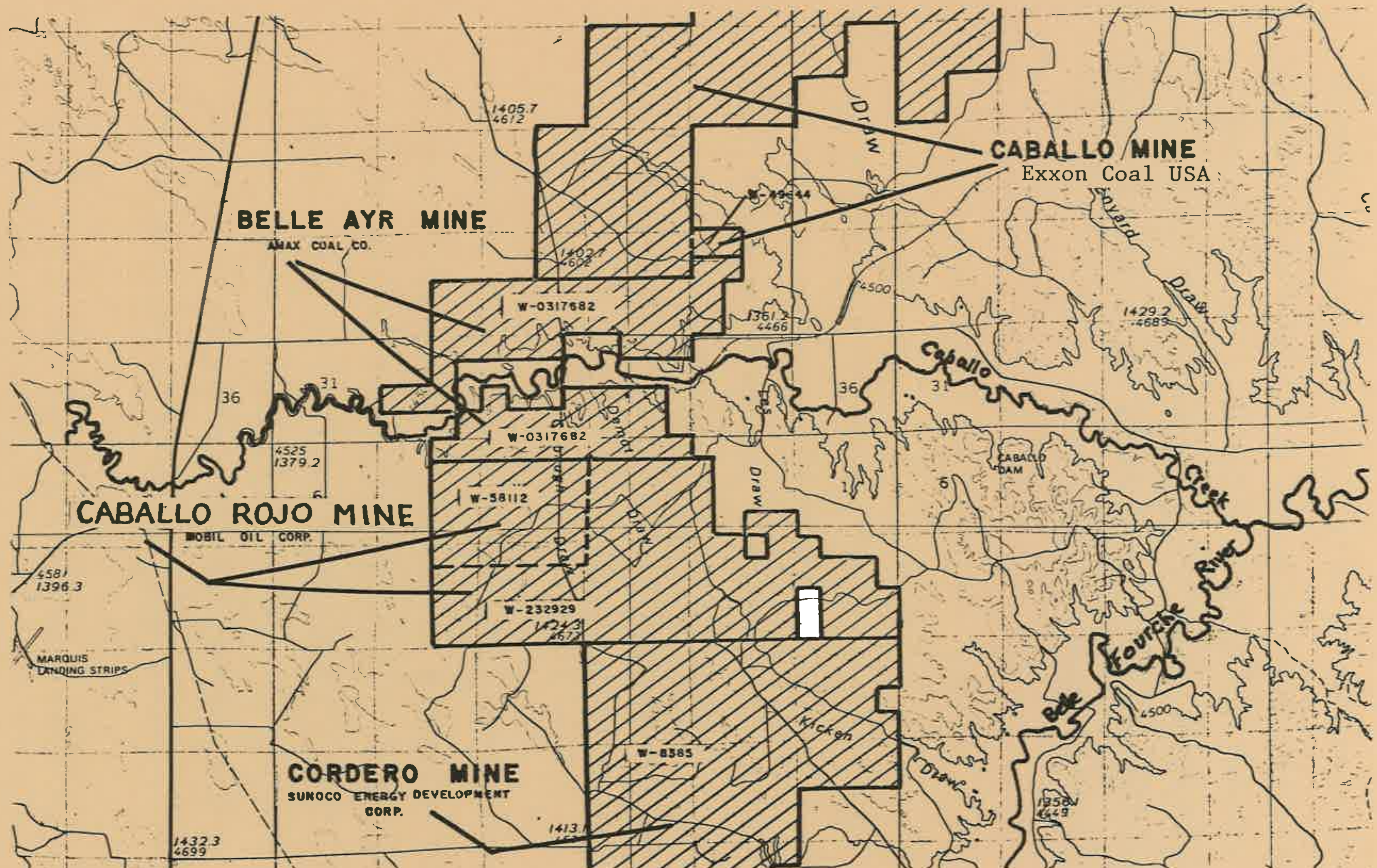

Fig. E-13 Location of the Bell Ayr mine, Campbell County, Wyoming.

are ephemeral except Duck Nest Creek which is intermittent. Because of the climate and the type of streams in the area, flow is extremely variable, and water quality is generally poor. The drainages have largely been diverted around the mining operation, and stream channel restoration plans have been developed on the basis of detailed channel geometry and geomorphological studies.

AMAX (1980) studies indicated that the clinker, coal, alluvium, and sandstones of the Wasatch and Fort Union Formations function as aquifers. The alluvium of the Caballo Creek valley is composed of about 30 feet of sand, silt, and clay and is recharged by subcropping coal, scoria, and sand paleochannels in the Wasatch overburden (and in limited areas by Caballo Creek itself). The alluvium, in turn, provides a baseflow component to Caballo Creek. Sand paleochannels also supply baseflow to Duck Nest Creek.

Mining is taking place on two large ranches where the principal agricultural activity was uncontrolled livestock grazing. Farming was limited to very small acreages for short time periods. Hayfields occur along Caballo Creek downstream from the permit area. Cropland is limited by precipitation and the depth, texture, permeability, and slope of the soils. Tillage agriculture in this part of Campbell County is reported to be a break-even or net-loss operation in most years.

Caballo Creek has been determined to be an alluvial valley floor. Portions of the valley to be mined are subirrigated and portions have the potential to be flood irrigated. Assessments of material damage and significance to farming were not made because the mine is protected by the grandfather clause from these alluvial valley floor provisions (WDEQ-LQD, 1982).

1. Restoration of Essential Hydrologic Functions. AMAX's plan for restoring the essential hydrologic functions of the Belle Ayr minesite includes reconstruction of the surface-water drainage system and important parts of local ground-water resources.

AMAX carefully documented the existing channel characteristics of Caballo Creek and then developed detailed postmining channel specifications. A new channel for Caballo Creek will be established with approximately the same gradient, elevation, and sinuosity as the existing channel. With the planned postmining configuration of Caballo Creek, the quantity and quality of flow are expected to closely approximate premining conditions. AMAX also provides discussions (though less specific than those for Caballo Creek) of channel reconstruction plans for Duck Nest Creek and the other minor tributaries to Caballo Creek.

Re-creation of local aquifers will be accomplished by selective placement of materials with similar hydraulic characteristics and in

sufficient cross-sectional size to restore important premining aquifer functions. Two shallow sand paleochannels cross the permit area north to south and carry a relatively large amount of water. Reconstruction of these two paleochannels will be accomplished by selective placement of preexisting sand paleochannel materials. One of these paleochannels (sand paleochannel A) was reconstructed in March 1980 and recovery of water levels in it has already begun (fig. 3.7-1, Belle Ayr permit application, AMAX, 1980). AMAX expects that due to the nature of the paleochannel material, which predominantly quartz sand, little change will occur to the already marginal quality of ground water.

Restoration of the alluvial aquifer of Caballo Creek will be started first by the placement of a silty shale to (1) "perch" the alluvial aquifer and maintain a saturated zone tied to the stream's channel, and (2) provide horizontal and vertical control to stabilize the creek. No silty shale will be used where the sand paleochannel aquifer interfaces with the alluvial aquifer. The alluvial aquifer material, which will include material salvaged along Caballo Creek, will then be placed in the same cross-sectional shape and area as the the premining alluvial aquifer. The alluvial material will consist of 60 percent sand, 10 percent very fine sand, 10 percent silt, and 20 percent clay. AMAX assumes that with these alluvial material characteristics and the planned placement scheme, the alluvial aquifer's premining underflow and storage components and water quality will be restored. However, no documentation of this statement is provided.

Terraces will be constructed along Caballo Creek with material suitable for plant growth and resistant to lateral erosion. AMAX expects that the planned terrace configuration, coupled with reconstruction of the alluvial aquifer, will restore premining subirrigated conditions of the lower terraces.

D. Underground Mining and Alluvial Valley Floor Protection in Colorado.*

The Colorado Mined Land Reclamation Division (CMLRD) has established a procedure for evaluating and monitoring the effects of mining under important streams. In this procedure, CMLRD assesses a mining and reclamation plan and makes a prediction of subsidence and related site-specific hydrologic effects on the overlying stream and alluvial system. Because of the present state of the art, predictions of subsidence and how subsidence will manifest itself at the surface are generally qualitative, and, therefore, related hydrologic impact assessments are also qualitative.

The potential hydrologic effects of underground mining resulting

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*Although no mining and reclamation plans for underground mines related to alluvial valley floors have been identified which have specifically resulted in modification of underground operations in order to protect alluvial valley floors, a basic conceptual approach, utilized by the State of Colorado, for evaluating and monitoring the effects of underground mines on drainages is presented in the following discussion.

from subsidence include draining of overlying aquifers through subsidence fractures, losses of surface flow into subsidence fractures that reach the ground surface, and initiation of gullying or ponding where uneven settling affects the existing stream gradient. Undermining of subirrigated alluvial valley floors presents the greatest concern. The possible resultant loss of shallow ground water, associated with subirrigation, through subsidence fractures may represent a situation where preservation or restoration of the alluvial valley floor's essential hydrologic functions cannot be achieved.

To protect water rights and alluvial valley floors, CMLRD also analyzes underground mining and reclamation plans for mitigating measures that can be implemented if subsidence were to occur. Mitigation of the effects of underground mining has included limited extraction mining (such as at Grand Mesa Coal Company's Red Canyon mine, in west-central Colorado, where coal extraction is limited to 50 percent). In addition, identification of alternative water supplies and providing engineering plans to assure delivery of water supplies (via pipeline, ditches, etc.) are accepted measures for mitigating some of the hydrologic effects of underground mining.

During active mining, CMLRD requires a detailed monitoring system which evaluates both subsidence and related hydrologic effects. Subsidence effects are monitored at the ground surface by use of

elevation control points. The monitoring pattern is generally a grid of control points in the shape of a cross over the first mine panel, with control points spaced at 0.1 to 0.2 times the overburden depth. Areas mined by longwall methods or by other high-extraction technologies generally subside rapidly (usually within weeks). With limited-extraction mining, the time of subsidence is impossible to predict.

The hydrologic effects of underground mining are monitored in overlying surface drainages, in surrounding wells, and within the mine itself. In the mine, points of ground-water inflow (e.g., floor, wells, roof, or composite) are generally measured monthly. Total pumpage from the mine and consumption by the mining operation are monitored. Water levels in wells and streamflow in the vicinity of the mine are also monitored. Variations observed in flow or water level at the monitoring sites, as well as variations in water chemistry, are used to evaluate the hydrologic effects of subsidence.

CMLRD has supported the concept of mining test panels at higher rates of coal extraction in areas with low risk (e.g., no stream, buildings, etc.) to allow site-specific evaluation of subsidence and related hydrologic effects. Following a sufficient test period, the results of the subsidence and hydrologic monitoring programs are reviewed, and the mine recovery rates are adjusted and balanced against the risks involved.

The types of evaluation procedures and mitigating measures just described would clearly be applicable where underground mines may affect alluvial valley floors and special protection measures may be necessary. Considerable site-specific information is necessary regarding subsidence and local hydrologic conditions before accurate predictions can be made. For this reason, CMLRD has taken a conservative approach when water resources may potentially be impacted by underground mining operations.

An example of a mining plan that provides a good analysis of subsidence and the hydrologic effects of underground mining is the CF & I Steel Corporation's (1980) mining and reclamation plan for the Maxwell and Allen mines in Las Animas County, Colorado.

E. White Rocks Sand and Gravel Pit.*

White Rocks is an open-pit sand and gravel mining operation approximately 3.5 miles east of Boulder, Colorado. The pit, which has been operating since 1973, covers approximately 250 acres and is in the Boulder Creek valley. The operation is the south of Boulder Creek, a west-to-east-flowing perennial stream. The northern extent

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*White Rocks is a sand and gravel operation near Boulder, Colorado, which is operated by Flatiron Sand and Gravel Company. This noncoal operation is discussed here because it implements an innovative mining and reclamation practice which protects a subirrigated area adjacent to the mine from being dewatered.

of the pit is approximately 200 feet south of the creek. The site lies within the 100-year flood plain of Boulder Creek and is riparian in nature, with low-lying sedge meadows and a mixture of grasses and introduced weeds. Some cottonwoods and willows are present in the valley. The flood plain of Boulder Creek is approximately 1,500 to 2,000 feet wide and is characterized by marshes, oxbow lakes, meander scars, and stream terraces.

The sand and gravel which is mined is in glacial and alluvial deposits overlying the Pierre Shale and Fox Hills Sandstone. The sands and gravels are approximately 13 to 20 feet thick. Overburden consists of silty to sandy loam, which ranges in thickness from 0.5 to 5 feet.

The sand and gravel in the mine area is an aquifer. Ground-water depths range from zero to 2 feet in the spring and during summer runoff periods, and from zero to 5 feet during the fall and winter. Irrigation return flows in the valley also cause saturation locally. Based on ground-water levels in the valley, it has been determined that ground water in the area discharges to Boulder Creek. The many wells in the Boulder Creek valley are completed in the alluvial sands and gravels. These wells are used for both domestic and stock-watering purposes.

Land use in the area of the White Rocks pits is agricultural, with the predominant use being cattle grazing during some parts of the year. The area is marshy during the spring and summer, when the water table is high, and irrigation return flows from upper areas pass near the minesite.

1. Protection of the Hydrologic System. Dewatering of the White Rocks pit is necessary because of the extent of shallow ground-water in the vicinity of the pit. The dewatering is accomplished by means of a trench excavated around the exterior of the pit. Based on aquifer characteristics determined through pump tests, drawdowns in the alluvial aquifer were expected to be approximately 1,500 feet from the pit boundary. However, the monitoring of ground-water levels has indicated some lowering of the water table in the immediate vicinity of the pit, but no water level effects have been identified at distances greater than 150 feet from the pit.

Due to landowner concerns for the adjacent lands west of the pit regarding the lowering of the water table and the resultant adverse impacts on subirrigated vegetation and marshy areas near the pit, the operator has installed an impermeable barrier along the western exterior of the pit to sustain ground-water levels in this area. In April 1978, a compacted barrier of shale was placed along the outer face of the dewatering trench on the western side of the White Rocks Pit. The barrier is approximately 0.5-mile long and is constructed

directly on the impervious Pierre Shale. The material for the barrier was excavated from the Pierre Shale. The barrier is sloped up from the bottom of the dewatering trench at a 4:1 slope (fig. II-A-9 of the permit application). The maximum vertical thickness of the barrier is approximately 70 feet. Figure II-A-9 of the application identifies a key and a toe filter; however, no information is provided as to the materials used to construct these features of the barrier. In addition, no design compaction rate for the impermeable barrier is specified.

Ground-water level measurements collected since 1978 indicate that the barrier has functioned well, maintaining ground water at high levels in the area west of the White Rocks pit. Subirrigation and marshy conditions in the area appear to have been maintained. In addition, field observations indicate that the structural integrity of the barrier has not been adversely affected by the build-up of water pressure on the western side of the barrier.

Although not clearly delineated in the permit application, it is presumed that following mining, the impermeable barrier will be removed, inasmuch as the planned postmining configuration for the pit is a series of lakes which must receive ground-water inflow from the west. The permit application notes that the planned series of lakes may result in a lowering of the water table in the alluvial aquifer by 4 to 6 feet in the area adjacent to the pit at a distance not to

exceed 200 to 500 feet from the pit boundary. This may result in some adverse effects on subirrigated vegetation in the immediate vicnity of the reclaimed White Rocks pit.

2. Evaluation of Impermeable Barrier to Maintain Subirrigation. The utilization of an impermeable barrier at the White Rocks pit to maintain subirrigation may have direct applicability to coal mining operations where subirrigation in immediately adjacent areas must be preserved. However, prior to utilization of this technique at particular coal minesites, the following questions and/or concerns should be addressed:

1. The local hydrologic conditions to be preserved (e.g., shallow alluvial water table) must be thoroughly understood (particularly in relation to the mining operation).

2. On the basis of these hydrologic conditions, detailed site-specific barrier designs must be developed, including types of materials, compaction rates, and structural design (e.g., necessary barrier length to maintain sufficiently high water levels and potential for mass failure and risk to life and property).

3. The material underlying the impermeable barrier must be evaluated to assure that it is sufficiently impermeable to provide an appropriate base for the barrier.

4. The construction of an impermeable barrier must be assessed from an operational standpoint (e.g., in terms of equipment availability and probability of meeting design specifications).

5. If the impermeable barrier must remain in place after mining (in order to preserve subirrigation adjacent to the mine), the predicted long-term integrity of the barrier and resultant impacts on water levels in adjacent areas must be addresssed.

F. Summary: Comparative Evaluation of Alluvial Valley Floor Restoration Plans.

This section provides detailed reviews and evaluations of plans for the restoration of essential hydrologic functions associated with alluvial valley floors. The following is a comparative evaluation focusing on some of the different approaches.

1. Flood Irrigation. Reclamation of flood irrigation (or its capability) is approached in all plans by restoring surface landforms suitable for flood irrigation and, most importantly, by restoring a stable stream channel. Several similarities exist among the three plans reviewed (South Fork Spring Creek, East Fork Coal Creek, and Caballo Creek). All plans depend on these assumptions:

1. Streamflow will be nearly the same after mining as compared to premining flow conditions.
2. The texture of the postmining valley substrate will approximate the premining valley fill texture.
3. Suitable soils for flood irrigation agricultural activities can be isolated and respread on the restored valleys.
4. Postmining topography can have greater contiguous areas of relatively flat land, better suited to irrigation than the premining topography.

Beyond the points mentioned above, the Spring Creek and Caballo Creek plans diverge in design concept from the East Fork Coal Creek plan. The two former plan designs of the postmining stream valley rely heavily on existing landforms as an estimate of the postmining

configuration that would be most stable. This approach is consistent with the geomorphic approach described in previous sections of this appendix. NERCO's plan for South Fork is particularly noteworthy because of the detailed field studies made which clearly showed the range in various stream characteristics and led to an understanding of the geologic or hydrologic reason for the range. The reclamation design then incorporated values for each identified characteristic appropriate for the assumed postmining conditions.

The East Fork Coal Creek reclamation plan takes the opposite tack. Because of the observed instability in the natural channel system, reconstruction of landforms similar to the existing ones was not considered approrpiate. Instead, a channel design was developed using a number of engineering flow predictions and empirical relationships for channel width, stream pattern, and other parameters of the postmining drainage system. The biggest problem in using such an approach is that, although the various equations and relationships were developed for a range of data, the basis for applying these relations to ephemeral streams is often weak.

For example, ARCO determined the size of the restored "pilot channel" by estimating the 2-year flood from an empirical relationship (Craig and Rankl, 1977). A better approach would have been to determine the size of the active channel in the stream and to design the postmining channel from this preexisting channel. Because the

active channel is considered to be a reflection of frequent, or recent, flow events occurring in a drainage basin, it is a good estimate of the channel capacity and configuration required for the postmining channel. Channel size is another example. The channel width was determined solely by increasing the design width (and thus reducing flow depth and velocity) to the point that no erosion was predicted to occur. However, the likelihood that floodflows might concentrate within the channel, causing incision and higher flow velocities, was not considered important. Design values developed in the office should be taken to the field and compared with existing conditions. Similarly, the design values for other channel and meander parameters developed from empirical relationships should be checked against actual field data, and discrepancies between the two data sets should be evaluated by a geomorphologist.

In addition to comparing and evaluating design parameters developed from engineering or empirical methods with the preexisting channel characteristics, an evaluation of the geomorphic history and existing condition of the drainage basin should be made. For East Fork Coal Creek, the decision to attempt to stabilize the reclaimed channel may be counter to how the drainage basin as a whole is responding to its prevailing climatic and land-use patterns. The condition of the existing valley bottom is a function of drainage basin conditions, and without some changes in the upstream areas, the expected stabiliziation may not occur.

Design of a postmining drainage system should be based upon geomorphic indications of stability in the natural drainage system, thereby increasing the likelihood of achieving a postmining drainage system which is capable of supporting potential flood irrigation agricultural activities. If data on the natural state of the stream cannot be collected, data from stable reaches up- or downstream from the reach in question can generally used.

2. Subirrigation. The mining and reclamation plans for South Fork Spring Creek and Caballo Creek include detailed plans to restore subirrigated conditions to affected valley areas. Both reclamation plans have several points in common:

1. The alluvial fill is selectively salvaged for later replacement in the reconstructed alluvial aquifer.
2. A fine-grained perching bed is established beneath the replaced alluvium.
3. The alluvial aquifer water budget is assumed to be approximately the same before and after mining. The last assumption is acceptable if supporting data are available; however, frequently this assumption represents an oversimplification of a set of very complex processes occurring in an alluvial ground-water system, thus promoting acceptance of a simple (and perhaps inappropriate) design concept for restoration of subirrigated conditions.

In addition to replacing fine-grained material under the alluvial aquifer, the plan for South Fork Spring Creek provides for compaction beneath the restored alluvial aquifer to further reduce downward percolation and to alleviate potential problems with uneven settling.

This represents a sound concept that should be used in most situations involving restoration of alluvial aquifers. Percolation losses from the saturated alluvium certainly have the potential to cause uneven settling that could destroy the restored aquifer. This potential problem was not addressed for the Belle Ayr mine.

The Spring Creek alluvial aquifer restoration plan, where the alluvium is comprised of sorted gravel, sand, and finer material, acknowledges that the hydraulic conductivity of these materials will likely be decreased after they are moved and mixed. Conversely, the sand paleochannel at the Belle Ayr mine is primarily a massive sandy body, and mixing of these materials may not substantially alter the hydraulic characteristics of the material. However, decreases in hydraulic conductivity may occur in the alluvial materials present along Caballo Creek after they are moved and mixed.

Design of the South Fork Spring Creek subirrigated area involves the placement of additional gravels in specified sequences and in a set, overall configuration in order to provide subirrigation in the lower reaches of the restored stream. The Caballo Creek plan simply calls for restoring the alluvium to a configuration similar to that which existed prior to mining. The Spring Creek alluvial aquifer reconstruction plan is more complex and will require more detailed monitoring to assure that the proper hydraulic characteristics have been incorporated into the postmining alluvial aquifer in order to

restore subirrigaton. However, the greater care taken in determining design parameters for the aquifer should result in greater success.

Overall success of the ground-water restoration plan for the alluvial and paleochannel aquifers at the Belle Ayr mine lies principally in the operational success of selectively salvaging particular aquifer materials and the proper placement of these materials to achieve the desired hydraulic characteristics. AMAX's restoration plan is notable because of its attempt to weave together the aquifer and channel reconstruction plans into an integrated hydrolgic system.

Several areas of concern exist, however, in AMAX's restoration plan. The permit appliation contains limited information with respect to:

1. The design compaction and expected long-term permeability of the silty shale layer used to perch the alluvial aquifer.
2. The expected postmining hydraulic conductivities of the sand paleochannel and alluvial aquifers (due to handling and mixing of material in salvaging and replacement).

Without a better understanding of the actual permeability of the silty shale layer and the hydraulic conductivity of the artificial aquifers, this plan may not work as expected. Further study of the paleochannel aquifer already re-created at the mine should help answer these questions.

The restoration plan for the South Fork Spring Creek alluvial aquifer is based on a more detailed look at how subirrigation is currently achieved. The water balance calculated for the existing aquifer is used as the design criterion for the restored aquifer. Although the components of the restored aquifer are different from those in the existing aquifer, the water balance and area of subirrigated land are similar to the premining conditions. The main concerns, then, with the South Fork Spring Creek alluvial aquifer plan relate to how accurately NERCO has defined the existing water balance and to how convincing are NERCO'S assumptions of the restored components of the aquifer. MDSL (1982) identified many of these concerns. Important concerns are whether:

1. The clinker layer of the alluvial aquifer will be saturated at all times and, thus, enable capillary rise of water up into the gravels and silts replaced above the clinker (fig. E-4).

2. NERCO's estimates of postmining hydraulic characteristics of the different aquifer materials are correct.

The restoration of subirrigated conditions is in its elementary stages of development, and very creative restoration plans are likely to be developed in the future. The assumptions regarding water supply, water quality, and the hydraulic characteristics of subirrigated alluvial systems should be carefully reviewed to minimize the risk of failure in these ventures. In all cases, it is imperative that comprehensive monitoring be undertaken to provide detailed documentation upon which future subirrigation restoration plans may be formulated.

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federal register

Tuesday
June 28, 1983

Part III

Department of the Interior

Office of Surface Mining Reclamation and Enforcement

Permanent Regulatory Program; Alluvial Valley Floors; Final Rule

DEPARTMENT OF THE INTERIOR

Office of Surface Mining Reclamation and Enforcement

30 CFR Parts 701, 785, and 822

Permanent Regulatory Program; Alluvial Valley Floors

AGENCY: Office of Surface Mining Reclamation and Enforcement, Interior.

ACTION: Final rule.

SUMMARY: The Office of Surface Mining Reclamation and Enforcement (OSM) is issuing rules governing surface coal mining operations on or near alluvial valley floors (AVF's). The rules amend several definitions, permit requirements and performance standards associated with AVF's, and provide regulatory authorities with flexibility as to the amount of information that has to accompany permit applications for mining on or near AVF's. They allow pemit applicants to request expedited determinations of whether statutory exclusions apply. In addition, they conform the rules to a district court decision which caused OSM to suspend a number of provisions dealing with AVF's.

EFFECTIVE DATE: July 28, 1983.

FOR FURTHER INFORMATION CONTACT: Mark Boster, Branch of Environmental Analysis, Office of Surface Mining, Department of the Interior, 1951 Constitution Avenue, NW., Washington, D.C. 20240; 202-343-2156.

SUPPLEMENTARY INFORMATION:

I. Background

On June 11, 1982 (47 FR 25486), OSM published a notice of proposed rulemaking to amend 30 CFR Parts 701, 785 and 822 relating to permit requirements and performance standards governing surface coal mining operations on or near alluvial valley floors. No public hearings or public meetings were requested. During the comment period, which extended to September 10, 1982, OSM received numerous comments from State agencies, industry and environmental groups.

The Act

The Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. 1201 *et seq.* (the Act), provides specific protection for AVF's in addition to the general environmental protection performance standards applicable to AVF's. Section 701(1) of the Act defines alluvial valley floors as "unconsolidated stream laid deposits holding streams where water availability is sufficient for subirrigation or floor irrigation agricultural activities * * *," excluding upland areas.

Section 510(b)(5) of the Act requires surface coal mining operation permit applications to demonstrate affirmatively and the regulatory authority to find in writing that a number of requirements unique to AVF's will be satisfied. That section applies only to proposed surface coal mining operations located west of the 100th meridian west longitude. Section 510(b)(5)(A) requires a permit application to demonstrate that the surface coal mining operation would "not interrupt, discontinue, or preclude farming on alluvial valley floors that are irrigated or naturally subirrigated * * *." Two exceptions from this requirement are provided in Section 510(b)(5)(A). The first is for undeveloped rangeland which is not significant to farming. The second allows mining when the regulatory authority finds that mining activities will interrupt "such small acreage as to be of negligible impact on the farm's agricultural production."

In addition, Section 510(b)(5)(B) of the Act requires a demonstration that the mining would not materially damage the quantity or quality of water in surface of underground water systems that supply the AVF's referred to in Section 510(b)(5)(A) of the Act on which farming cannot be interrupted, discontinued, or precluded.

A proviso in Section 510(b)(5) of the Act exempts from the requirements of Section 510(b)(5) those surface coal mining operations which in the year preceding the enactment of the Act (August 3, 1977) produced coal in commercial quantities and were located within or adjacent to AVF's or had specific permit approval from the State regulatory authority to conduct surface coal mining operations on AVF's.

A further proviso, in Section 506(d)(2) of the Act, excludes from the requirements of Section 510(b)(5) of the Act any land that is the subject of an application for renewal or revision of a permit issued under the Act which is an extension of the original permit, insofar as: (1) The land was previously identified in a reclamation plan submitted under Section 508 of the Act, and (2) the original permit area was excluded from the requirements of Section 510(b)(5) of the Act under the proviso of Section 510(b)(5) for operations which produced coal in the year preceding enactment of the Act.

Regardless of whether the standards of Section 510(b)(5) of the Act for protection of AVF's apply, the hydrologic protections of Section 510(b)(3) and 515(b)(10)(F) on the Act apply. Section 515(b)(10)(F) requires mining operations to minimize disturbances to the prevailing hydrologic balance at the minesite and in associated offsite areas and to the quality and quantity of water in surface and ground water systems both during and after surface coal mining operations and during reclamation by preserving throughout the mining and reclamation process the essential hydrologic functions of AVF's is the arid and semiarid areas of the country.

Regulatory Implementation of AVF Requirements

The Act's AVF requirements have been implemented in three principal places in 30 CFR Chapter VII. The major terms pertaining to AVF's are defined in 30 CFR 701.5. Specific permit application requirements for AVF's are set forth in 30 CFR 785.19. Finally, additional specific performance standards for AVF's are set forth in 30 CFR Part 822.

A discussion of particular features of the amended rules are included below in "II. Discussion of Comments and Rules Adopted."

II. Discussion of Comments and Rules Adopted

A. General Comments

Some commenters were concerned about the deletion of much of the informational requirements and explanations contained in the previous rules. The commenters felt that this information was valuable in providing guidance to both operators and regulatory authorities and that it should not be deleted for the purpose of reducing the overall size of the regulations. One of the commenters felt this information was necessary to assure consistency among States.

OSM carefully evaluated the detailed informational requirements contained in the previous alluvial valley floor regulation. The changes to the alluvial valley floor rules will eliminate much of the confusion about protection requirements of the Act and will provide regulatory authorities with flexibility to reflect site-specific conditions. Much of the technical information being eliminated, while not wrong, adds unnecessary length and confusion to the regulatory structure. Most of the eliminated material will continue to be available in guidelines and is the type of information likely to be valuable in

asisting the regulatory authority in making its determinations. Elimination of the detailed informational requirements from every permit application will not result in the regulatory authorities making unsupported or technically inadequate determinations with respect to alluvial valley floors. Every decision must be based on and supported by adequate technical data and analyses regardless of whether each detail or study is enumerated in the rules.

Comments were received by OSM with regard to the usage of various "areas" used in the alluvial valley floor rules. For example, in § 785.19(a)(1) of the proposed rules, one commenter pointed out that the term "potentially impacted area" was used, but the term was not defined and did not offer the same degree of protection as the term "mine plan and adjacent area" which was used in the previous regulations. Similarly, one commenter noted the proposed substitution of the term "outside the mine site" for "not within the affected area" in § 822.11 was not clear since this new term was not defined.

OSM has evaluated the commenters' concerns noted above and has reviewd proposed § 785.19 and Part 822 with respect to the use of terms relating to "areas." Based on this review, OSM has made changes to §§ 785.19(a)(1), 785.19(b)(1), 785.19(d)(1), 822.11(a), 822.11(b) and § 822.13 to provide clarification. OSM intends that a broad area should be referenced in § 785.19 (a) and (b) with respect to alluvial valley floor determinations and applicability of statutory exclusions. Thus, determinations as to the presence or absence of alluvial valley floors or the applicability of statutory exclusions by the regulatory authority will relate to the "permit area and adjacent area." The adjacent area, in this context, will be the area outside the permit area where an alluvial valley floor is or reasonably could be expected to be adversely impacted by proposed surface coal mining operations, including probable impacts from underground workings. Thus, OSM has maintained the introduction of § 785.19(a)(1) which refers to permit and adjacent area, but has not included the term "potentially impacted" as a modifier for "area" in this section since this phrase is not defined.

With regard to § 785.19(d)(1), OSM has used the phrase "permit area or adjacent area" for the phrase "potentially impacted area" which was used in the proposed rules. Use of the new terms will clarify that permit applications for proposed operations potentially affecting alluvial valley floors must cover both the permit area and the adjacent area.

Similarly, in proposed § 822.11(a), relating to the essential hydrologic functions of alluvial valley floors, OSM has deleted the proposed language "in associated offsite areas" and "outside the mine site" because these terms are not defined and may be confusing in the context used. OSM has replaced these phrases with the phrase "not within the permit area." Similar changes have been made to §§ 822.11(b) and 822.13. These changes will provide improved clarity to the rule.

A commenter asked OSM to clarify whether all hydrologic, geologic, and biologic permitting requirements under other parts of the permanent regulatory program are applicable in addition to specific requirements for alluvial valley floors. The specific requirements for AVF's complement the other requirements of the permanent regulatory program which continue to be applicable by their own terms.

B. Section 701.5—Definitions

Alluvial Valley Floors: One commenter recommended deletion of the current definition for the term "alluvial valley floors" since it merely mirrors the statute. The commenter also suggested a definition which requires that subirrigation or flood irrigation agricultural activities exist. In addition, the commenter noted that the concept of "potential" alluvial valley floors (from the standpoint of potential flood irrigation or subirrigation agricultural activities) should be deleted from the rules since it is inconsistent with Section 510(b)(5)(A) of the Act. The commenter provided a more concise definition which deleted reference to areas excluded under the definition of alluvial valley floors. The commenter asserted that such exclusions should be addressed under the definitions of particular terms related to the alluvial valley floors provisions.

OSM considered the commenter's recommendations and concerns and has elected to maintain the existing definition for the term "alluvial valley floor." Because this definition is workable, and is derived directly from Section 701(1) of the Act, it has been retained. OSM disagrees with the commenter's concern about "potential" alluvial valley floors. An area either is an alluvial valley floor or it is not. The key to the definition is the relationship between the hydrology of the area and agricultural activities. The definition in Section 701(1) of the Act requires that "* * * water availability is sufficient for subirrigation or flood irrigation agricultural activities * * *." Thus, the definition included in the statute requires that there be sufficient water available for flood irrigation or subirrigation agricultural activities. This requirement implies that an area may be designated as an alluvial valley floor (assuming other applicable criteria are met) based on the availability of sufficient water to support potential flood irrigation or subirrigation agricultural activities, even if there were no such activities currently in existence within the area.

Agricultural Activities: Various comments were made with respect to the proposed definition of the term "agricultural activities." One commenter suggested that agricultural activities, with respect to alluvial valley floors, be a "controlled and managed" use (*i.e.*, not to include undeveloped rangeland with natural vegetative growth). Another commenter recommended substituting "agricultural products" for "animal and vegetable life" to clarify that wildlife usage is not an agricultural activity. One commenter suggested that the definition be modified to: (1) Include only areas where a reasonable attempt has been made to incorporate modern agricultural practices; (2) eliminate the phrase "but are not limited to" since all types of agriculture which could benefit from the increased availability of water are in fact listed; and (3) state that areas with flood irrigation or subirrigated vegetation which are not commonly grazed, hayed, or cropped due to inaccessibility and/or "poor palatability" do not constitute agricultural activities. It was also suggested by one commenter that the examples of agricultural activities be eliminated due to redundance.

OSM has reviewed and evaluated the general comments submitted on the proposed definition of the term "agricultural activities" and related comments pertaining to "farming." Although the Act and OSM's rules use both terms, the meaning of both terms, as regards AVF's is the same. Therefore the final definition of "agricultural activities" will also serve as the definition of "farming." The usage of one of these terms rather than the other in Part 822 and § 785.19 is discussed later in this preamble.

OSM agrees with the commenter that agricultural activities must be "controlled and managed." However, no change is necessary in the final rule since agricultural activities are related to "production" which includes deliberate management of the property to produce commercial animal or

vegetable life. The definition does include pasturing and grazing lands. The legislative history supports the concept that these valley floors provide for subirrigation or flood irrigation of crops and grazing lands (*e.g.* see H.R. Rept. No. 95-218, 95th Cong. 1st Sess. at 116 (1977)).

No change in the rule is necessary to exclude wildlife usage as an agricultural activity. The definition excludes wildlife usage as an agricultural activity through the phrase "for the production of animal or vegetable life." In addition, OSM considers the list of examples of agricultural activities to be informative and not redundant.

There is no statutory basis for requiring that agricultural activities, with respect to alluvial valley floors, must include only areas where attempts have been made to incorporate modern agricultural practices. Thus OSM has rejected that suggestion. The phase "but not limited to" is appropriate terminology to assure that all agricultural activities either enhanced or facilitated by subirrigation or flood irrigation are included in the definition. In response to the commenter who felt that the definition should clearly state that areas not commonly grazed, hayed, or cropped do not constitute agricultural activities, this concern is adequately addressed under the definition of "alluvial valley floor" which requires that sufficient water be available for subirrigated or flood irrigated agricultural activities. If the valley area in question is not suitable for flood irrigated or subirrigated agricultural activities, the area should not qualify for alluvial valley floor designation.

Two commenters expressed concern with respect to the addition of the phrase "based on regional practices" to the definition of the term "agricultural activities." One commenter asserted that there is no statutory justification for addition of this phase. This commenter went on to note that, contrary to the proposed preamble, adding this phase to the definition causes the definition to be confusing. It was pointed out that the addition of a reference to regional practices would result in: (1) Considerable differences of opinion as to what constitutes "accepted" regional agricultural practices; (2) discrimination against innovation; and (3) the tendency to foreclose the potential for technological advances or market changes that would significantly alter regional agricultural practices (particularly as it applies in § 785.19 (a) and (b)(2)). The other commenter stated that addition of regional agricultural practices to the definition would expand alluvial valley floor designations in some places and diminish such designations in others (*e.g.*, what areas can be farmed and what areas cannot be farmed). The commenter stressed that the use of regional agricultural practices in the definition or agricultural activities results in ambiguity.

OSM disagrees with the comments received with respect to the addition of the phrase "based on regional practices" and has included the phrase in the final definition of agricultural activities. The determination of whether an alluvial floor exists should be based on agricultural practices within the region encompassing the AVF and not upon speculation on what changes in agriculture may take place at some indeterminate time in the future or on agricultural activities that may be accepted in other parts of the country or the world. For example, it would be inappropriate to judge the existence of an alluvial valley floor in Wyoming by whether it fits the category for agricultural activities in Illinois or Indiana and vice versa.

Moreover, the addition of this phrase is not inconsistent with the Act. In fact, the Act itself recognizes the regionalized importance and character of AVF's and has applied the special requirements only to arid and semi-arid regions of the country. As included in §§ 785.19(a)(2)(ii)(B) and 785.19(b)(2)(ii), regional agricultural practices will play an important part in assessments of flood areas to farming.

Two commenters expressed concern with the portion of the proposed definition of agricultural activities which referred to "watering of livestock." Both commenters stated that watering of livestock is not an agricultural activity related to the availability of water of subirrigation or flood irrigation agricultural activities. More specifically, one commenter stated that the definition, as proposed, implies that watering of livestock is enhanced by subirrigation or flood irrigation.

OSM agrees that watering of livestock in and of itself is not related to subirrigation or flood irrigation and has revised the definition accordingly. However, although it is not necessary to list this activity in the definition, the watering of livestock, when considered in context with "grazing" of livestock, could be an activity included within the meaning of grazing and can be considered to be an integral component of livestock grazing operations.

One commenter noted that with respect to alluvial valley floors, the Act references arid and semiarid areas of the country west of the 100th meridian west longitude. The commenter went on to note that in the area of the Pacific Northwest, west of the Cascade Mountains, average annual precipitation is greater than 40 inches, and therefore, the area should not be classified as arid and semiarid. The commenter encouraged OSM to recognize such areas for exclusion from the alluvial valley floor requirements.

OSM considered these comments with respect to the applicability of the alluvial valley floor requirements to areas of relatively high precipitation west of the 100th meridian and agrees that the alluvial valley floors protection provisions are applicable to only arid and semiarid areas (*i.e.*, areas experiencing water deficits, where water use by native vegetation equals or exceeds that supplied by precipitation) in the western United States. A specific exclusion for the kinds of areas mentioned by the commenters is unnecessary within the context of this rule and is already accounted for in the definition of "arid and semiarid area" in 30 CFR 701.5. State and regional specific differences can be accommodated through the individual State program development and approval process, under Subchapter C of 30 CFR Chapter VII.

Essential Hydrologic Functions: The proposed rule identified two alternative definitions for the term "essential hydrologic functions." The first proposed alternative (Alternative 1) retained the operative portion of the previous definition but eliminated the explanation of various terms used in the definition. Alternative 2 would have separately defined essential hydrologic functions of an alluvial valley floor for the periods during and after mining.

Numerous comments were received with respect to these alternative definitions for the term. The vast majority of commenters favored Alternative 1 over Alternative 2. The principle reason stated for this preference was that Alternative 2 appeared to many commenters to be more of a performance standard than a definition. In addition, one commenter noted that the split in the definition as function of the phase of mining was confusing when considered in light of the performance standards of § 822.11 (a) and (b). One commenter pointed out that the essential hydrologic functions of an alluvial valley floor do not change because the phase of the mining operation has changed. One commenter stated that he believed Alternative 2 represented a duplication of performance standards in Part 822 and that the proposed reference to not

destroying natural vegetation would have been unduly restrictive since this activity is allowed if the area can be reclaimed in accordance with the Act. One commenter asserted that the definition of the term should be based on the physical and hydrologic characteristics of the alluvial valley floor, irrespective of the mining activity. Another concern voiced with respect to Alternative 2 was that this definition would have implied that mining an alluvial valley floor would be allowed even where the alluvial valley floor has been designated significant to farming by the regulatory authority. Another commenter maintained that Alternative 2 would limit the essential hydrologic functions to maintenance of the water balance upstream and downstream to preserve natural vegetative cover and erosional balance. This commenter also asserted that Alternative 2 would allow greater disruption of mines adjacent to alluvial valley floors. In addition, with respect to Alternative 2, one commenter stated that there was no basis in the Act or the legislative history to define essential hydrologic functions as a function of the mining process. This same commenter also noted that Alternative 2 would have included no protection for agricultural activities during mining and that making water usefully available following mining does not provide the same degree of protection as the previous rule and is inconsistent with previous § 785.19(d)(2).

Finally, two commenters endorsed Alternative 1 but recommended that the definition be modified to state clearly that essential hydrologic functions for an alluvial valley floor protect and support flood irrigation or subirrigation agricultural activities. One commenter also stated that if Alternative 1 were selected that the word "extended" be eliminated because this term implies a long period of time and thus would rule out any functions that support the use of spreader irrigation. Several other commenters stated their preference for Alternative 2.

OSM has reviewed the comments with respect to Alternative 1 and 2 for the definition of the term "essential hydrologic functions" and has selected Alternative 1 in this final rule. This definition, which is a continuation of the key portion of the previous rule, meets the intent of the Act and provides consistency with Parts 785 and 822 of the rules with respect to alluvial valley floor protection. The final definition is based on physical and hydrologic characteristics which support flood irrigation or subirrigation agricultural activities on alluvial valley floors (irrespective of the particular phase of the mining activity). Use of the phrase "provides a water supply during extended periods of low precipitation" is consistent with the basic water supply situation in alluvial valley floor areas and does not rule out consideration of spreader irrigation.

One commenter asserted his support for general shortening of the definition of "essential hydrologic functions." However, two commenters expressed concern that elimination of Paragraphs (a)–(d) represented a significant deletion since information contained in these paragraphs was substantive and valuable with respect to the definition. One of these commenters stated that OSM is wrong in saying in the preamble to the proposed rules that this information was excessive. The commenter argued that this information helped distinguish the functions of collecting, storing, regulating, and making water available to agricultural activities on the alluvial valley floor. Another commenter expressed concern that deletion of an explanation of the specific roles of alluvial valley floors in the water supply for agricultural activities makes the role of the regulator in preventing damage more difficult. This commenter went on to note that guidelines which contain such information will not have the same force as regulations and will be subject to interpretation and different implementation. The commenter also asserted that the shortened version of the definition would work against consistency (particularly on Federal lands).

OSM has reviewed and evaluated the concerns expressed by the commenters with respect to the shortening and simplification of the definition of the term "essential hydrologic functions." As discussed elsewhere in this preamble, the technical information contained in the deleted paragraphs will continue to be available and is more appropriately addressed in guidelines related to alluvial valley floor protection (see OSM's Alluvial Valley Floor Identification and Study Guidelines). The fact that these explanations are in guidelines and not in regulations does not dilute the protection of AVF's because the operative portion of the definition is retained as is the performance standard using the phrase in § 822.11.

A few commenters recommended completely new definitions for the term "essential hydrologic functions." One commenter suggested adding the two alternatives together to define the term in general and also to describe how the definition would be applied during and after mining. The commenter also suggested some wording changes (*i.e.*, substitution of the word "capability" for the word "role;" adding "to plants" after the words water supply; and deleting "maintenance of water balance") since the Act requires minimizing disturbance to the hydrologic balance. Two commenters recommended a definition of the term "essential hydrologic functions" which consolidates Alternatives 1 and 2. This recommended definition attempted to combine the concept to maintain the overall erosional balance of the area while supporting agricultural activities with adequate water.

OSM has evaluated the definitions for the term "essential hydrologic functions" recommended by the commenters. For reasons previously cited in this preamble in support of Alternative 1, OSM finds that definitions for the term which incorporate elements of Alternative 2 are inappropriate. With regard to specific recommendations for wording changes in the definition, the language provided in Alternative 1 is similar to that proposed by the commenters and provides equal protection under the Act. With respect to the recommendation to add language noting that water is to be supplied "to plants," this addition is not needed since the previous sentence refers to supplying water which is usefully available to agricultural activities.

Materially Damage the Quantity or Quality of Water: With respect to the proposed definition of the phrase "materially damage the quantity or quality of water," one commenter recommended that deletion of the phrase "agricultural activities" from the definition and substitution of the term "farming." The commenter asserted this term was more appropriate for the definition because Section 510(b)(5) of the Act is specifically concerned with farming rather than agricultural activities. Another commenter requested that the language "any portion of an alluvial valley floor" be reinstated in the definition. A commenter also pointed out that the supporting preamble to this definition infers that material damage would be allowed if no "systemwide" impacts would result. This commenter went on to state that the preamble is in error and that under the previous rules, specific factors such as flow rate and storage volumes had to be considered. Finally, one commenter requested that the following phrase be retained from the previous definition: "changes that significantly and adversely affect the composition, diversity, or productivity of

vegetation dependent on subirrigation, or which result in changes that would limit the adequacy of the water for flood irrigation of the irrigable land and acreage existing prior to mining."

OSM has evaluated the comments noted above with respect to this definition, and has elected to adopt the definition, as proposed, with two minor revisions. The first includes changing the word "and" to "or" in the defined phrase. Use of the word "and" in the proposed rules was inadvertent. It is clear from the wording of Section 510(b)(5)(B) of the Act that the correct terminology should be "materially damage the quantity *or* quality of water." (Emphasis added.) This correction has also been made where the phrase is used in § 785.19(e)(2)(ii) and in § 822.13(a)(3). The second change is the insertion of the word "coal" in the phrase "surface coal mining and reclamation operations" because that is a defined phrase. Thus, the new definition provides that "materially damage the quantity or quality of water" means to degrade or reduce by surface coal mining and reclamation operations the water quantity or quality supplied to the AVF to the extent that resulting changes would significantly decrease the AVF's capability to support agricultural activities.

In response to the specific comments noted above, OSM has amended the definition of the term "materially damage the quantity or quality of water" to simplify and clarify its application and to reflect a district court decision in *In re: Permanent Surface Mining Regulation Litigation*, Civ. No. 79–1144 (February 26, 1980). That case held that the material damage requirements of Section 510(b)(5)(B) of the Act only apply to alluvial valley floors to which the exclusions of Section 510(b)(5)(A) of the Act do not apply.

Although Section 510(b)(5)(A) of the Act uses the term "farming," it is appropriate to use the term "agricultural activities" in the definition of "materially damage the quantity or quality of water." First, as defined in § 785.19(b)(3), a farm is one or more land units on which agricultural activities are conducted. Therefore, assessing the impacts of the surface coal mining and reclamation operation on the quantity or quality of water that is supplied for the agricultural activities which comprise the farming operation is equivalent to assessing the impacts on the farming operation. Therefore, the use of the term "agricultural activities" in the definition is consistent with the Act.

In response to the commenter's concern about the deletion of the phrase "any portion of an alluvial floor" and also to the commenter's concern that material damage is now allowed under the definition if "systemwide" impacts do not occur, the definition does not change the level of protection of water systems that supply alluvial valley floors which are significant to farming. Although some impacts to the water systems of such alluvial valley floors may occur as a result of surface mining, this is allowed under the Act. These impacts, whether systemwide or occurring on a portion of the alluvial valley floor, must not be of such magnitude as to significantly decrease the capability of the alluvial valley floor to support agricultural activities.

The language of the previous definition which related to adversely affecting vegetation or limiting flood irrigation is not necessary in the definition. Such impacts on the alluvial valley floor will be identified under the new definition in the determination whether the quantity or quality of water that supplies the alluvial valley floor will be degraded or reduced. By focusing the definition on the capability of the alluvial valley floor to support agricultural activities, the emphasis is properly placed on providing the protection that Congress intended.

One commenter pointed out that proposed § 785.19 allowed material damage to waters supplied to an alluvial valley floor that may be mined under exclusions of Sections 510(b)(5)(A) and 506(d)(2) of the Act. The commenter went on to note that this appears to be in direct conflict with Sections 510(b)(3) of the Act and 515(b)(10)(F) of the Act.

OSM has evaluated the commenter's concerns and has concluded that §§ 785.19 and 822.12 are in conformance with the Act, comply with the district court's decision as to the applicability of Section 510(b)(5)(B) of the Act, and do not conflict with Sections 510(b)(3) or 515(b)(10)(F) of the Act. More specifically, if the exclusions of Sections 510(b)(5)(A) and 506(d)(2) of the Act do not apply, then the material damage requirements of Section 510(b)(5)(B) apply. In all cases, the essential hydrologic functions of alluvial valley floors must be preserved (or restored) under Section 515(b)(10)(F) of the Act and the requirements of Section 510(b)(3) of the Act, relating to prevention of material damage to the hydrologic balance outside the permit area, must also be met. Regulations implementing Section 515(b)(10)(F) of the requirements are properly included in § 822.11 and 30 CFR 786.19(c), respectively. (The requirements of Section 510(b)(3) of the Act will continue to be implemented in the final revisions to the hydrology and permitting rules that are now pending.) Previous § 785.19 attempted to combine the requirements of Sections 510(b)(3) and 510(b)(5)(B) of the Act. These final rules do not combine these statutory requirements.

A commenter stated that the shorter and more general definition of the term "materially damage the quantity or quality of water" would weaken alluvial valley floor protection required by the Act. In addition, the commenter asserted that the proposed definition would lead to problems in consistency in measuring material damage (*i.e.*, the requlatory authorities implementing the Act would use inconsistent criteria). This comment was also related to the proposed removal of criteria in previous § 785.19(e)(3) for assessing material damage. In addition, one commenter stated his belief that elimination of the criteria of previous § 785.19(e)(3) for determining whether an operation will cause material damage does not eliminate counterproductive or burdensome rules. The commenter asserted that removal of the criteria in and of itself is actually counterproductive to the intent of the Act in setting national standards. The commenter went on to remark that it is burdensome to applicants and affected citizens to attempt to discern the meaning of the term with the criteria given in the proposed rules. The commenter also asserted that criteria themselves should be left in the rules (rather than in guidelines) to assure appropriate public notice, the opportunity for public comment, and a more accountable program if changes are proposed.

OSM has carefully evaluated the comments received on shortening of the definition of the phrase "materially damage the quantity or quality of water" and also with respect to deleting from the rules the specific criteria for determining material damage. As noted earlier, the deletions from the definition refocus but do not narrow the definition. The principal elements of the previous definition are maintained in the definition, albeit in a more general manner. Deletion of the specific material damage criteria from § 785.19(e) is also justified. The performance standard regarding material damage is retained. Detailed technical information is more appropriately addressed in guidelines. More specifically, OSM's Alluvial Valley Floor Identification and Study Guidelines address various criteria and approaches for assessing material damage of the quantity or quality of water that supplies alluvial valley floors. The national standard adopted allows regional considerations to be

dealt with. Inclusion of the detailed criteria in guidelines will allow regulatory authorities to determine which criteria are relevant in particular situations.

One commenter recommended amending the definition of "materially damage the quantity of water" to specify that the use of adjudicated water rights by an operator shall *not* constitute material damage to water supplying an alluvial valley floor. The commenter went on to assert that it was not the intent of Congress to preempt provisions of State law with regard to adjudicated water rights.

The requirements related to material damage are not related to provisions of State law with regard to adjudicated water rights. No change in the regulation is necessary.

One commenter argued that the proposed definition of "materially damage the quantity or quality of water" significantly alters the interpretation of material damage and the applicability to water supplying alluvial valley floors. The commenter noted that OSM's basis for this change is the February 26, 1980, district court decision which, at the time of the comment, was under appeal. The commenter noted the basis for the appeal (including the requirements of Section 510(b)(3) of the Act) and also asserted that promulgation of this rule prior to resolution of the issue by the U.S. Court of Appeals is premature on the part of OSM. This same commenter, in commenting on proposed § 785.19, expressed concern that this section reflected an "abandonment" by OSM of its appeal.

In response to the February 1, 1983, remand order of the U.S. Court of Appeals, No. 80-1810 (D.C. Cir.), OSM has reconsidered the issues contained in the briefs of the parties. OSM has determined that Judge Flannery's interpretation of the scope of Section 510(b)(5)(B) of the Act is consistent with the Act's intent. Thus, the definition of the term "materially damage the quantity or quality of water" has been amended to reflect that material damage requirements of Section 510(b)(5)(B) of the Act apply only to alluvial valley floors where the exclusions of Section 510(b)(5)(A) of the Act do not apply.

Subirrigation: Two commenters expressed concern with the proposed definition of the term "subirrigation" since technical information present in the previous definition was deleted in the proposed definition. One of these commenters specifically stated that information in the previous rule as to how to identify subirrigation is valuable and should be maintained. However, another commenter expressed general support for shortening of the definition. One commenter, in addition to noting concern with deletion of technical factors describing subirrigation, also expressed a concern that no reference was included in the rule or the preamble to guidelines which could assist in determination as to the presence or absence of subirrigation. This commenter went on to contend that as a result of this deletion of technical information, consistency would suffer, mining on Federal lands would not be uniformly administered, and that States will seek to gain advantages over each other by varying definitions of the term. This commenter went on to assert that the overall effect of this change would be the undermining of the program.

OSM rejects the commenters' concerns and concludes that the deletion of technical factors from the definition of the phrase, considering the extensive treatment of the concept of subirrigation in OSM's guidelines, will *not* lead to inconsistency, undermining of the program, nonuniform administration of mining on Federal lands, or the use of a modified definition by States to gain advantage over each other. Under the final definition, "subirrigation" means the supplying of water to plants from underneath or from a semisaturated or saturated subsurface zone where water is available for use by vegetation. The complex (and often site-specific) technical factors relating to subirrigation are addressed in detail in OSM's Alluvial Valley Floor Identification and Study Guidelines.

A number of commenters expressed concern that the proposed deletion of technical factors from the definition of the term "subirrigation" would result in expansion of areas which would be classified as being subirrigated. More specifically, one commenter asserted that the proposed definition expanded the scope of potential subirrigation acreage considerably (to include almost every valley in the West). This commenter went on to recommend the deletion of the phrase "from underneath or from a semi-saturated or saturated subsurface zone where water is available for use by vegetation." Another commenter echoed the same concerns and also suggested including the concept of capillary action from underlying aquifers and related root penetration. The latter comment was supported by another commenter who noted that root penetration and capillary rise is important to include in the definition since they represent the major biologic and hydrologic mechanisms by which water is made available to agricultural plants from underlying water sources. Another commenter suggested adding the phrase "underlying alluvial aquifers" to distinguish from colluvial water bearing material which is not protected by the alluvial valley floor provisions. Similarly, one commenter recommended the deletion of the language "or the existence of a semi-saturated or saturated subsurface zone" since semi-saturated conditions may occur in upland areas and be associated with the soils' moisture-holding capacities and not subirrigation related to a shallow alluvial water table. Finally, one commenter recommended insertion into the definition of the phrase "in sufficient quantity to support farming during moisture deficient months," thereby, reinforcing the focus of subirrigation in alluvial valley floors to provide water during the dry months.

OSM has carefully reviewed the specific comments noted above with respect to the definition of "subirrigation." There was no intent in the proposed rules to expand the definition of the term, the previous definition of which included the criticized language. The proposed definition appropriately defined the term when considered in the context of the other terms associated with alluvial valley floor protection (*e.g.*, alluvial valley floors, agricultural activities and essential hydrologic functions). The comments expressed above, regarding colluvial water, upland areas, and supplying sufficient water, are addressed in the definitions of these other terms.

One commenter recommended adding the word "agricultural" to modify "plants" to focus the definition on agriculturally useful species based on the objectives of alluvial valley floor protection.

The commenter's recommended addition to the definition is unnecessary because the term is used in the context of alluvial valley floors for which water is available for flood irrigation and subirrigation agricultural activities. Therefore, when the definition of subirrigation is considered in association with other terms related to alluvial valley floor protection (*e.g.*, alluvial valley floors and agricultural activities), the term relates primarily to vegetative species which are useful from an agricultural standpoint.

One commenter recommended a total revision to the definition because virtually all water is supplied to plants from "underneath" and subirrigation waters are not defined separately from water normally available to plant roots through precipitation, infiltration, and percolation. The commenter's proposed new definition included the following:

(1) Water delivered to the soil profile rooting zone is in quantities greater than normally available from precipitation, infiltration, and percolation; (2) subirrigation is normally derived from capillary rise from saturated shallow subsurface zones to provide water in moisture deficient months; and (3) subirrigation is identified by a significant portion of the root mass within the capillary fringe area.

OSM agrees that the points the commenter has raised are important aspects of subirrigation. However, the more general definition of this term, as adopted, is more appropriate given variations in site-specific conditions associated with subirrigation agricultural activities on alluvial valley floors. Further, the technical aspects proposed by the commenter for inclusion in the definition are more appropriately addressed in guidelines associated with the alluvial valley floor protection provisions of the Act and the rules. The commenter is referred to OSM's Alluvial Valley Floor Identification and Study Guidelines which provide extensive guidance as to the technical aspects of subirrigation. Therefore, OSM rejects the proposed definition of the commenter.

Unconsolidated Streamlaid Deposits Holding Streams: A number of comments were submitted on the definition of the phrase "unconsolidates streamlaid deposits holding streams." Three commenters stated that the definition, as proposed, was inappropriate because the scope of the definition would have been broadened by the inclusion of perennial, intermittent and ephemeral streams. In particular, the commenters asserted that the inclusion of ephemeral streams in the definition was inappropriate. The commenters recommended changes to the definition that stated that only streams of significant size and with seasonally consistent flow to enhance agriculture should be considered under definition of unconsolidated streamlaid deposits holding streams for the purpose of alluvial valley floor protection. One commenter recommended deletion of all references to stream type due to redundancy. Two other commenters recommended that the definition be modified to acknowledge the importance of the hydrologic aspects of streamlaid deposits in sustaining agricultural productivity.

One commenter suggested that the term "geologic deposits comprising" floodplains be added to the definition of "unconsolidated streamlaid deposits holding streams" for technical correctness. Two commenters suggested that the definition be revised to state clearly that upland areas are *not* unconsolidated streamlaid deposits.

One commenter suggested that floodplains and terraces with slopes greater than 2 percent should not be considered floodplains for the purpose of alluvial valley floor designation because under these slope conditions, alluvial deposits begin to feather out and a mixture of alluvial deposits begin to feather out and a mixture of alluvium and colluvium occurs. Another commenter pointed out that the width of the valley often restricts farming, and this should have a bearing on alluvial valley floor designation. This commenter went on to assert that an alluvial valley floor less than 100 feet in width represents a practical farming limit.

One commenter expressed concern that the deletion of the quantitative size-related criteria for channels (*i.e.*, bankfull width and depth) would lead to inconsistency in implementation of the alluvial valley floor protection provisions. This commenter also noted that no technical justification had been provided to support this deletion. However, one commenter expressed support for elimination of the numerical channel size criteria.

One commenter requested that the definition for this term be deleted in its entirety since the proposed definition: (1) Defined only where these deposits may be found and not what they are; and (2) improperly included all streams and did not consider whether the stream (and its related aquifer) supply water in sufficient quantities for flood irrigation and/or subirrigation agricultural activities. One commenter proposed a definition which: (1) Is restricted to sediments in lower portions of valleys laid down by streams; (2) excludes colluvial deposits; and (3) contains streams with sufficient water for subirrigation or flood irrigation agricultural activities.

OSM has evaluated the concerns of all of these commenters and has decided to accept the suggestion to delete the definition of "unconsolidated streamlaid deposits holding streams." OSM has concluded that the statutory language "unconsolidated streamlaid deposits holding streams," is the clearest statement of congressional intent regarding the applicability of the alluvial valley floor requirements. *E.g.*, see 123 Cong. Rec. S8083 *et seq.* (Daily ed., May 20, 1977), or H.R. Rep. 95-218, 95th Cong., 1st Sess. (1977) at 119. The legislative history of the Act demonstrates that Congress was vitally concerned with the definition of the term "alluvial valley floor" and carefully chose the geologically derived phrase "unconsolidated streamlaid deposits holding streams." A regulatory gloss in this instance would be overly restrictive.

The proposed definition was not intended to broaden the types of streams covered by the rule. The type or size of the stream is relevant only in determining the availability of water for flood irrigation or subirrigation agricultural activities. The proposed rule was intended to remove an unnecessary technical stream size threshold from the rules which would not be correct in all instances. The removal of the definition accomplishes this.

As a general approach, regulatory authorities must consider the nature of the deposits, their geomorphic characteristics, and stream and valley characteristics (*e.g.*, type stream, channel size, valley width, and area) during the evaluation of alluvial valley floors and related unconsolidated streamlaid deposits holding streams. OSM's Alluvial Valley Floor Identification and Study Guidelines address the issue of unconsolidated streamlaid deposits in relation to flood irrigation and subirrigation agricultural activities and include specific reference to the channel dimension criteria which have been deleted in the final rules.

C. Section 785.19—Permit application requirements

The rules on permit application requirements for surface coal mining and reclamation operations involving alluvial valley floors which are contained in previous § 785.19 have been amended in this final rulemaking to delete duplicative information contained in other parts of the rules; delete detailed technical information and requirements that are not necessary for the protection of alluvial valley floors; respond to the February 26, 1980, district court decision; and establish a procedure by which the regulatory authority, as early in the permit process as possible, can identify alluvial valley floors and determine whether the statutory exclusions are applicable.

The final rule eliminates previous § 785.19 (a) and (b) in order to avoid repeating regulatory language adequately covered by other provisions of the rules. The "Scope" paragraph is unnecessary because the succeeding paragraphs describe the persons to whom the rule will apply. Similarly, the prohibition in previous § 785.19(b) against mining without a permit is also covered elsewhere in the rules.

Section 785.19(a) Alluvial valley floor determination: Final § 785.19(a)(1)

allows applicants to request the regulatory authority to make a determination whether, in an arid and semiarid area, valley floors in the proposed permit area or adjacent area are alluvial valley floors. It also requires sufficient data be submitted by the applicant to make this determination and allows the regulatory authority to request additional information from the applicant. Final § 785.19(a)(2) requires the regulatory authority to make a written determination and requires it to determine an alluvial valley floor exists if unconsolidated soil deposit holding streams are present and sufficient water is available to support agricultural activities as evidenced by certain activities. Final § 785.19(a)(3) allows that further consideration of § 785.19 is not required if an alluvial valley floor is found not to exist in the proposed mining area or adjacent area pursuant to Paragraph (a)(2).

Final § 785.19(a) has only a few changes from the proposed rules and they are discussed with the following comments. One of the changes was made in final § 785.19(a)(1). As an initial step in the permit process, permit applicants "may" (as opposed to "shall" in the proposed rules) request the regulatory authority to make an alluvial valley floor determination. This request should be discretionary on the part of permit applicants. The regulatory authority has the responsibility in each case to determine whether an AVF is present. The discretion is provided to allow an operator to seek such a determination at the outset of the permit application process.

Previous § 785.19(c) enabled the operator to obtain a determination of the existence of an alluvial valley floor prior to submittal of the permit application. Unfortunately, in every situation it required an extensive amount of information to be submitted for the regulatory authority to base its determination of the existence of an AVF. This included results of a field investigation of the proposed permit area and adjacent area. The investigation had to include detailed geologic, hydrologic, land use, and soils and vegetation studies. The studies had to include maps of unconsolidated streamlaid deposits holding streams, maps of streams, surface watershed, flood plains, terraces, maps of land subject to agricultural activity, etc. In addition, documentation based on environmental monitoring, measurements, and representatives sampling was required, together with infrared aerial photographs.

Previous § 785.19(c) is renumbered as § 785.19(a). OSM is amending this section by deleting the unnecessary detailed technical information and study requirements. The changes do not alter the requirement that adequate data and analysis are required to support an alluvial valley floor determination by the regulatory authority. The primary difference is that these rules allow the regulatory authority to adjust the type of information and level of analysis to better reflect site-specific conditions. The enumeration of the specific types of maps, monitoring, documentation, and photographs that has to be included in all studies is eliminated. This change should result in substantial time and cost savings in those situations where the presence or absence of an alluvial valley floor is obvious and not controversial. A new § 785.19(a)(3) is included to clarify that, if alluvial valley floor areas are not identified, the applicant could complete the permit application process without further consideration of § 785.19.

One commenter requested deletion of the term "alluvial valley floor" in § 785.19(a) and insertion of the term "significant agricultural activities in the valley floor."

OSM has evaluated the commenter's request and finds that this section properly uses the term "alluvial valley floor." More specifically, Sections 510(b)(5) and 515(b)(10)(F) of the Act use the term "alluvial valley floor" and not "significant agricultural activities on the valley floor." The term "alluvial valley floor" is defined in § 701.5 of the rules which parallels the definition in Section 701(1) of the Act. The Act is not limited in its application to "significant agricultural activities on the valley floor." Therefore, OSM finds that the use of the term alluvial valley floor in § 785.19(a) is appropriate.

A few commenters expressed concern with respect to the use in proposed § 785.19(a)(2)(ii)(B) of the phrase "capability of an area to be flood irrigated." One commenter suggested deletion of this phrase because there is no statutory basis for the concept. For example, the commenter noted that Section 510(b)(5)(A) of the Act refers only to alluvial valley floors that *are* irrigated or naturally subirrigated and that there is thus no inference to "capability" for irrigation.

The commenter went on to assert that congressional intent was to protect farming on alluvial valley floors which benefit from *existing* irrigation or subirrigation. Further, the commenter asserted that this portion of the rule imposes an intolerable burden on operators because virtually every acre of the West has "potential for irrigation" if economic, environmental, and technological constraints are ignored. Two commenters also recommended that the regulatory authority should consider "historically proven" capability rather than potential alone for determining flood irrigation capability.

The definition of the term "alluvial valley floor" in Section 701(1) of the Act speaks to water "availability" for subirrigation or flood irrigation. There is no requirement that the area be currently irrigated or have a "historically proven" capability for irrigation to be classified as an alluvial valley floor. In this instance, final § 785.19(a)(2)(ii)(B) has continued the requirements of previous § 785.19(c)(2). OSM does not concur with the commenter's assertion that "virtually every acre of the West" has the potential for irrigation. Past alluvial valley floor evaluations by OSM and State regulatory authorities have led to negative determinations of the potential for flood irrigation. OSM's Alluvial Valley Floor Identification and Study Guidelines provide guidance with regard to factors upon which to evaluate the potential for flood irrigation. More specifically, the guidelines refer to evaluations of regional flood irrigation practices and of water quantity and quality, soils, and topography to assess the potential for flood irrigation in valley areas. Economic, environmental, and technological factors are integral to the assessment of the potential for flood irrigation. Therefore, OSM rejects the recommendations and rationale of the commenters with respect to this issue.

Two commenters expressed support for early identification of alluvial valley floors without the submission of a complete permit application. However, one commenter expressed a number of concerns with regard to this idea. The commenter contended that the alluvial valley floor determination, as proposed, would require the regulatory authority to make a determination as to the existence of an alluvial valley floor on the basis of information available at an early stage of permitting. This commenter also pointed out that seldom, if ever, was there sufficient information available at the initial, pre-permitting stage of the approval process to make a final determination of the existence of an alluvial valley floor. The commenter went on to also point out that information needed for an alluvial valley floor determination is required in a normal permit application (*e.g.*, hydrology data base) and therefore, it is

illogical to require its presentation prior to permit application submission.

OSM has evaluated the commenter's concerns noted above and offers the following response. First, as was allowed by the previous rules, it is entirely appropriate for the alluvial valley floor permitting rules to provide for an operator to submit information prior to submission of a complete permit application relating to the presence or absence of alluvial valley floors in areas which will or may be affected by surface coal mining and reclamation operations. A resolution of this issue, or of the related issue pertaining to the applicability of a statutory exclusion, could be determinative as to whether mining will be allowed. An early determination that mining will be prohibited could spare an operator the expense associated with the filing of a complete permit application.

With regard to a commenter's inference that such preapplication determinations will be made with incomplete data, § 785.19(a)(1) specifies that the "regulatory authority may require additional data collection and analysis or other supporting documents, maps, and illustrations in order to make the determination." OSM wants to emphasize that in order for the regulatory authority to make a pre-application alluvial valley floor determination, sufficient data must be available . OSM agrees with the commenter that the data base for an alluvial valley floor determination and the hydrology data base are closely related, but this should not preclude early submission of such data to support an alluvial valley floor determination. However, in many cases, a complete permit application may be needed to assess the significance of an alluvial valley floor to farming, whether the quantity or quality of water supplying the alluvial valley floor will be materially damaged, and whether the alluvial valley floor's essential hydrologic functions will be preserved (or reestablished). Such information will be required for the regulatory authority to make the finding or § 785.19 (b) and (c).

One commenter suggested that OSM should incorporate into the alluvial valley floor rules a procedure for an early determination of alluvial valley floors without expensive preapplication studies.

Such a procedure is possible under the new rules. The extent of the information necessary to make the determination will depend upon the individual site. The commenter is referred to OSM's Alluvial Valley Floor Identification and Study Guidelines which provide various levels of analysis with respect to possible alluvial valley floors. More specifically, the commenter is referred to Part I of the guidelines which provides for basic geomorphic, water availability, and land use investigations which may indicate conclusively at an early stage of the proceeding, the presence or the absence of alluvial valley floors.

One commenter expressed concern with the application of the phrase "adjacent area" in the section and maintained that it is not defined in the rules nor used in the Act. This commenter went on to state that submittal of a complete alluvial valley floor permit application should not be required if the mine area is a small contributor to the total water flow in the valley. The commenter also suggested that Part 785 be changed to reduce the application requirements for these areas that contribute insignificant quantities of water to the alluvial valley floor.

Alluvial valley floor determinations and appropriate studies must be undertaken for proposed operations within a valley holding a stream or in a location where the adjacent area includes any stream in the arid and semiarid regions of the United States. With regard to alluvial valley floor protection, the concept of "adjacent area" is consistent with Sections 510(b)(5) and 515(b)(10)(F) of the Act because these sections intend protection of all alluvial valley floors that may be affected.

The term "adjacent area" is defined in the rules and refers to the area where a resource outside the permit area is or could reasonably be expected to be adversely impacted by mining (48 FR 14814, April 5, 1983). It is important to evaluate the presence of alluvial valley floors in these areas associated with surface mining and reclamation operations. If alluvial valley floors are present in the adjacent area, it is important to identify the importance of these alluvial valley floors to farming, to evaluate the potential of the proposed operation to materially damage the quantity or quality of water supplying them, and to assess their essential hydrologic functions. If it is determined that the area upon which the surface coal mining operations will be conducted contributes insignificant amounts of water to an alluvial valley floor in an adjacent area, the necessary studies should be designed accordingly. Again the commenter is referred to OSM's Alluvial Valley Floor Identification and Study Guidelines which provide guidance as to recommended studies for operations which may encounter alluvial valley floors in adjacent areas.

One commenter recommended deletion in § 785.19(a)(1) of the phrase "or in a location where the adjacent area includes any stream" because there is no justification to require an alluvial valley floor determination for areas that hold streams which are adjacent to alluvial valley floors.

OSM has reviewed the proposed language of § 785.19(a)(1), and concludes that the scope of this paragraph is correct in requiring an alluvial valley floor determination for areas adjacent to surface coal mining and reclamation operations which themselves are not immediately adjacent to alluvial valley floors. Therefore, OSM rejects the point of concern raised by the commenter.

One Commenter recommended replacement language regarding the studies necessary to demonstrate the existence of an alluvial valley floor as given in proposed § 785.19(a)(1). The commenter recommended the same studies be required but stated the studies should specifically be required to address the criteria of § 785.19(a)(2) and that the section should list sufficient information so that the regulatory authority can make an alluvial valley floor determination.

The commenter's suggestion with regard to the sufficiency of information is already included in § 785.19(a)(1) by the requirement for the regulatory authority to determine, based on either available data or field studies submitted by the applicant (or a combination of available data and field studies) the presence or absence of an alluvial valley floor. Information sufficiency is also emphasized by the last sentence of § 785.19(a)(1) which states that the "regulatory authority may require additional data collection and analysis or other supporting documents, maps, and illustrations in order to make the (alluvial valley floor) determination." OSM's Alluvial Valley Floor Identification and Study Guidelines also provide guidance as to geologic, hydrologic, land use, soils, and vegetation data and analyses which are oriented to the criteria of § 785.19(a)(2).

Two commenters expressed concern that use of the phrase "or historical" flood irrigation in § 785.19(a)(2)(ii)(A) presupposes that flood irrigation was successful and indicates that sufficient water is available to support flood irrigation agricultural activities. One commenter noted that abandoned facilities could be a strong indicator of non-alluvial valley floor status if abandonment was related to adverse hydrologic or soil conditions. The other

commenter recommended that language be added to modify "historical flood irrigation" to specify that the mere existence of historical flood irrigation may or may not provide evidence of sufficient water availability to support agricultural activities. This commenter recommended the addition of the phrase "demonstrated success" to modify historical flood irrigation.

OSM concurs with the concerns expressed by the two commenters and agrees that proposed § 785.19(a)(2)(ii)(A) was not clear with respect to this matter. Therefore, OSM has modified § 785.19(a)(2)(ii)(A) to refer simply to the "existence of current flood irrigation in the area in question," and has modified § 785.19(a)(2)(ii)(B) to refer to the "capability of an area to be flood irrigated, based on evaluations of typical regional agricultural practices, *historical flood irrigation*, streamflow, water quality, soils, and topography." (Emphasis added.) This modification clarifies the role of historical flood irrigation as an indicator of sufficient water availability for flood irrigation. The term "water yield" has been deleted from the revised § 785.19(a)(2)(ii)(B) since it was considered superfluous to the term "streamflow" which has been maintained in the paragraph. OSM's Alluvial Valley Floor Identification and Study Guidelines also address the studies necessary to evaluate historical flood irrigation as an indicator of sufficient water availability to support agricultural activities.

One commenter suggested a modification of the subirrigation criterion of § 785.19(a)(2)(ii)(C) to add "as evidenced by the presence of significant agricultural activities." The commenter went on to assert that this would cut down on field studies because if manageable agricultural activities are present and no obvious flood irrigation is present, one can infer that subirrigation is present.

OSM has evaluated the commenter's suggestion relative to the proposed language of § 785.19(a)(2)(ii)(C) and finds no basis in the Act of include the term "significant agricultural activities" with respect to an evaluation of the presence of subirrigation. The language of proposed § 785.19(a)(2)(ii)(C) appropriately addresses the criterion of subirrigation as provided for in the Act. ASM's Alluvial Valley Floor Identification and Study Guidelines address subirrigation field investigations in considerable detail.

One commenter stated his belief that the absence of currently developed agricultural activity should settle whether an area is a significant alluvial valley floor This commenter also contended that such an absence of agricultural activity represents a threshold decision that no alluvial floor exists unless the interruption is due to artificial interruption such as mining.

The commenter's proposal conflicts with the term of the statute. Specifically, the definition of "alluvial valley floors" in Section 701(1) of the Act refers to water availability for flood irrigation or subirrigation activities with no reference to currently developed agricultural activities in the determination of alluvial valley floors.

One commenter expressed the opinion that the presence or abandoned spreader dikes or other abandoned agricultural improvements should be accepted as conclusive proof of the insignificance of the area to agriculture, provided that it can be documented that abandonment was due to long-term inability of the land to support agricultural use.

OSM intends that in the evaluation of flood irrigated agricultural activities, an assessment of abandoned flood irrigation should be undertaken. Abandoned spreader dikes may be an indication that flood irrigation agricultural activities in a particular valley are not feasible. However, OSM does not concur with the position advanced by the commenter that abandoned spreader dikes (or other abandoned agricultural improvements) should be accepted as conclusive proof of the insignificance of the area to agriculture. Flood irrigation systems may be abandoned for a variety of other reasons (*e.g.*, water rights) and these should be evaluated in the course of the alluvial valley floor assessment. Based on this reasoning, OSM rejects this suggestion of the commenter.

One commenter recommended the addition of language to proposed § 785.19(a)(1) to require that data only with respect to "agriculturally significant" vegetation be collected. The commenter went on to emphasize that Congress was very specific about addressing only the agricultural aspects of alluvial valley floors. Therefore, the commenter contended that only data relative to agricultural production is important.

Final § 785.19(a)(1) specifies that studies shall include sufficiently detailed vegetation data and analysis to demonstrate the probable existence of an alluvial valley floor. OSM agrees with the commenter that the focus of the vegetative studies and analysis should be with respect to agriculturally important vegetative species. Final § 785.19(a)(1) contains general references to geologic, hydrologic, land use, soils, and vegetation data and analyses needed to demonstrate the probable existence of an alluvial valley floor. (The commenter is referred to OSM's Alluvial Valley Floor Identification and Study Guidelines which address the elements of an appropriate vegetation study related to alluvial valley floor assessments.)

Section 785.19(b) Applicability of statutory exclusions: The previous rules required that a complete permit application for mining operations be filed, including all hydrologic data, before the regulatory authority could make a determination of the applicability of the various statutory exclusions. In some cases, this procedure created an unnecessary amount of uncertainty and expense for the applicant and did not contribute to a higher level of environmental protection of the alluvial valley floor.

OSM is amending this procedure. If an alluvial valley floor is present, final § 785.19(b) provides that the operator may request that the regulatory authority make a determination of the applicability of the statutory exclusions of Section 510(b)(5) of the Act. The operator must submit sufficient data, information, and analyses to the regulatory authority to support the determination, and the regulatory authority may make the determination, based on this supporting material. The proposed phrase "applicant-submitted data" has not been adopted since it is subsumed within the term "available data." If the regulatory authority needs further information to determine whether the exclusions of the Act apply, it may request additional data collection and analyses, including submittal of a complete permit application.

Those circumstances excluded from the requirements of Section 510(b)(5) of the Act are set forth as statutory exclusions in § 785.19(b)(2). The first exclusion is for undeveloped rangeland that is not significant to farming and is set forth in § 785.19(b)(2)(i). The second exclusion, in final § 785.19(b)(2)(ii), is for small acreage with negligible impact on a farm's agricultural production.

The previous test for compliance with the small acreage exclusion was set forth in suspended § 785.19(e)(2) which provided: "The effect of the proposed operations on farming will be concluded to be significant if they would remove from production, over the life of the mine, a proportion of the farm's production that would decrease the expected annual income from agricultural activities normally conducted at the farm."

The February 26, 1980, district court decision, *In re: Permanent Surface*

Mining Regulation Litigation, supra, at pp. 45–53, held that this test was inconsistent with the Act because even interference with a small number of acres, a situation in which the Act does not intend mining to be precluded, may result in a decrease in a farm's income.

Under the final rule, negligible impact of the proposed surface coal mining and reclamation operation on farming will be based on the relative importance of the affected vegetation and water of the developed grazed or hayed AVF to the farm's production. This rule encompasses the salient non-suspended portion of previous § 785.19(e)(2).

The statement of what constitutes a farm is moved from previous § 785.19(e)(4) to final § 785.19(b)(3), but remains unchanged.

The third circumstance that would provide an exclusion from the requirements of Section 510(b)(5) of the Act, in final § 785.19(b)(2)(iii), accounts for the proviso in Section 510(b)(5) of the Act and its extension in the proviso in Section 506(d)(2) of the Act. Rather than having the substance of the provisos repeated a number of times in the rules, final § 785.19(b)(2)(iii) cross-references § 822.12(b) (3) and (4), which describes the provisos.

Several comments were received about the provisions of § 785.19(b). One commenter felt that the proposed change in § 785.19(b)(1) allowing the applicant to request a separate determination as to the applicability of a statutory exclusion could result in an interruption of the review process and the submission of data out of phase with other parts of the review process. Another commenter suggested that the proviso of Section 510(b)(5) of the Act should be contained in § 785.19(b)(2)(iii) and that this section be referenced in § 822.12(c) rather than as proposed (the reverse organization). One commenter indicated that the phrase "significant to agricultural activities" in proposed § 785.19(b)(2)(i) should be deleted because it expands the requirements of previous § 785.19(e)(2) that stated significance to agricultural activities is based on the relative importance of the vegetation and water of the developed grazed or hayed alluvial valley floors area to the farm's production. Finally, this same commenter felt the proposed § 785.19(b)(2)(ii) would have established an economic test for significance to farming, but in reality, there is no economic loss because the land owner is compensated by the operator.

OSM has reevaluated the requirements of § 785.19(b)(1) that provide for a separate determination of the applicability of the statutory exclusions from Section 510(b)(5) of the Act and finds no basis for the commenters' concern that these provisions could interrupt the review process. The regulatory authority may need to adjust its procedures slightly but this is certainly within the realm of reasonable administrative practice. With respect to the suggestion that OSM reverse the organization of §§785.19(b)(2)(iii) and 822.12(c), the change is unnecessary.

Finally, with respect to the comment concerning the application of the proposed phrase "not significant to agricultural activities," OSM has modified the final rule to refer to land on which "the premining land use is undeveloped rangeland which is not significant to farming." This properly describes the first circumstance excluded from the requirements of Section 510(b)(5) of the Act. The language the commenter referred to in previous §785.19(e)(2) concerning the "relative importance" of the "developed" AVF area is not pertinent in considering undeveloped rangeland.

Under these final rules, it is necessary to determine the "significance to farming" only with regard to the statutory exclusions for undeveloped rangeland. The applicability in §785.19(b)(2)(ii) of the second statutory exclusion is dependent upon the finding that small acreage affected will cause negligible impact on a farm's agricultural production. Also, the finding in final §785.19(e)(2)(i) relates to whether the proposed surface coal mining operation will interrupt, discontinue or preclude farming. Since neither of these other provisions relates specifically to a finding of "significance to farming," the language of previous §785.19(e)(2) referred to by the commenter is unnecessary.

A commenter expressed concern that the provisions of §785.19(b)(2) for identifying statutory exclusions before a complete permit application is submitted would burden the regulatory authority with a responsibility to make a determination without adequate information. This commenter also requested that the detailed technical data and informational requirements of the previous rule be retained.

The requirements of §785.19(b) do not require the regulatory authority to make a preliminary determination on the applicability of the statutory exclusions. The rules emphasize the importance of adequate information to support the determination. A regulatory authority that cannot make a supportable determination based on information submitted by the applicant must request additional data and/or analyses. This additional material could include a complete permit application.

As stated earlier, the detailed technical information of the previous rules need not be contained in the rules. Much of the material is already included in the guidelines on alluvial valley floors.

One commenter asserted that rangeland without improvements to increase productivity of vegetation should not be considered improved even if cross fencing, watering ponds, and other facilities normally associated with western rangeland are present.

OSM has reviewed the use of the term "undeveloped rangeland" in §785.19(b)(2)(i) and concludes that this subparagraph correctly implements the requirements of Section 510(b)(5)(A) of the Act with respect to undeveloped rangeland. The definition of "undeveloped rangeland" in § 701.5 of the rules simply refers to lands where the use is not specifically controlled or managed. Therefore, although not specifically stated in the rules, if fencing, watering ponds, and other facilities have been implemented to specifically support subirrigation or flood irrigation agricultural activities on the alluvial valley floor, such rangeland would be considered "improved." This is consistent with the guidelines and the approach taken by a number of western State regulatory authorities in implementation of the alluvial valley floor protection provisions of the Act.

One commenter pointed out that the Act is clear that unconsolidated streamlaid deposits alone do not constitute an alluvial valley floor. This commenter also noted that it is necessary to make a threshold determination that an alluvial valley floor does not exist where no consistent water supply is available to sufficiently sustain irrigated agricultural activities.

OSM concurs with the points made by the commenter. The necessary elements of an alluvial valley floor are addressed in §785.19(a)(2). Namely, the regulatory authority shall determine that an alluvial valley floor exists if unconsolidated streamlaid deposits holding streams are present *and* there is sufficient water available to support agricultural activities. No changes are required in the rules to reflect the points made by this commenter.

One commenter suggested that easily applied criteria on such characteristics as stream size and vegetation should be developed to exclude areas from alluvial valley floor studies.

In response to this comment, such uniform national standards are not easily developed. OSM has decided that

detailed criteria should be included in technical guidelines which support implementation of the alluvial valley floor protection provisions of the Act rather than in rules. The commenter is again referred to OSM's Alluvial Valley Floor Identification and Study Guidelines. These guidelines provide sizing criteria with respect to channel width and depth, valley width, and valley size and provide guidance with respect to criteria which may be used to exclude areas from consideration as alluvial valley floors. As with any guidelines, they may not be appropriate in every instance and a regulatory authority has the responsibility for making the final determinations based on the facts of the specific situation.

Two commenters pointed out that the proposed addition to § 785.19(b)(2)(ii) on "determining negligible impact on farming, if farming is already precluded because of physical or economic consideration," would have been an unnecessary addition. Both commenters noted that this was adequately covered under the statutory exclusion of § 785.19(b)(2)(i). Further, one of the commenters felt that the area would not be classified as an alluvial valley floor in the first place when regional agricultural practices are evaluated.

OSM has reevaluated the need for the additional regulatory language in § 785.19(b)(2)(ii) and agrees with the commenters that the proposed addition was not necessary and could have added confusion. The final rules have been modified to remove this language.

One commenter requested that the proposed sentence in § 785.19(b)(2)(ii) describing how to determine negligible impact on a farm's agricultural production be deleted from the rule and that the States be allowed to establish standards for negligible impact. This commenter pointed out that under the proposed rule, the regulatory authority would have to assess the life-of-mine effects rather than those over the permit term.

OSM has carefully evaluated the proposed changes to § 785.19(b)(2)(ii) concerning the determination of negligible impact on a farm's agricultural production. The agency disagrees with the commenter's assertion that requiring consideration of impacts of mining on alluvial valley floor production over the life of mine would be excessive and impose an unnecessary burden on both the operator and the regulatory authority. As indicated in the proposed rule, a time frame is necessary to measure the impact of mining on a farm's production. The expected life of the mine is the most reasonable and accurate time frame and was included in the previous rule. Further, consideration of impacts over such an extended period will reduce errors in measurement associated with normal expected fluctuations in a farm's annual output. Since an operator must submit information on all alluvial valley floors both in the permit area and in the adjacent area, the requirement should not significantly change the burden on the operator.

The final rule does not adopt the proposal to measure a farm's production based solely on typical farming practices in the region.

In reviewing the legislative history, it is apparent that the comparison to determine whether impacts are negligible must be made on a farm-by-farm basis rather than on a regional basis (123 Cong. Rec. S8039, May 19, 1977). While it may be appropriate to utilize typical farming practices in the region to assist in evaluating the impacts of mining on a farm, farm-specific practices may also be appropriate for consideration in a particular case. Therefore, OSM has dropped the proposed language for this rule and has maintained language similar to that contained in the previous rule. The phrase "The significance of the impact" contained in the previous § 785.19(e)(2) has been changed to "negligible impact" to be consistent with other changes to this section.

Varied opinions were expressed by commenters with respect to the definition of the term "farm" in § 785.19(b)(3). Three commenters recommended that the definition of farm be retained in the rules, as proposed, to provide clarity and avoid future controversy. However, two other commenters suggested that the definition of the term be deleted from the rules to provide flexibility. More specifically, these commenters suggested that the term "farm" be defined on a case-by-case basis to reflect variability in regional farming practices. One commenter also noted that considerable confusion existed in the proposed rules due to the unpatterned, interchangeable use of the terms "farming" and "agricultural activities."

OSM has considered the comments with respect to the definition of the term "farm" in § 785.19(b)(3), and concludes it is important to include the definition of this term in the rules to provide necessary clarification. In addition, the definition of farm in the rules provides the necessary flexibility to take into account regional agricultural practices and also provides important information with respect to the relationship of a "farm" and "agricultural activities."

To provide further clarification, a number of changes have been made in the rules to provide consistency in the use of the term "farming" and "agricultural activities." More specifically, the term "farming" has been substituted for the term "agricultural activities" in §§ 785.19(b)(2)(i), 785.19(d)(2)(ii), 822.12(a)(1), and 822.13(a)(2) to provide consistency with the Act. These substitutions have been made where the rules implement the requirements of Section 510(b)(5)(A) of the Act. This section of the Act refers to the protection of "farming" (while the definition of alluvial valley floor in Section 701(1) of the Act uses the more general term "agricultural activities"). Therefore, substitution of the term "farming" for "agricultural activities" has occurred in the sections noted above which relate to the statutory exclusions if the area is undeveloped rangeland not significant to farming or relate to whether the operation will avoid the interruption, discontinuance, or preclusion of farming. These changes will provide needed clarification and consistency in the rules and will more closely meet the intent of the statute with respect to alluvial valley floor protection.

Section 785.19(c) Summary denial of permit: If the regulatory authority were to determine under final § 785.19(b)(2) that the statutory exclusions of Section 510(b)(5) of the Act do not apply to the applicant, the applicant would have a number of choices: (1) Attempt to obtain a permit by meeting the standards of Section 510(b)(5) of the Act; (2) Withdraw its application; or (3) Under new § 785.19(c), request the regulatory authority summarily to deny the permit prior to submittal of the entire permit application based on a finding that mining would be precluded under Section 510(b)(5) of the Act. Such a denial could enable the applicant to initiate a request for an exchange of land under the coal exchange program required by Section 510(b)(5) of the Act. This is a more logical procedure than previously existed and its implementation will avoid the problem with the previous rules that possibly required the operator to collect and submit unnecessary data and analyses.

One commenter fully supported proposed § 785.19(c) to enable the regulatory authority to determine that an alluvial valley floor area is significant to farming without the operator having to submit a complete application. Another commenter noted that the proposed addition might lighten the workload of the regulatory authority

without compromising environmental protection. But the commenter pointed out the potential for abuse through collusion using such procedures. Finally, a commenter felt it was unclear how the regulatory authority can deny the application if it cannot make the findings of § 785.19(e)(1). The commenter felt the regulatory authority would have to make the finding in § 785.19(e)(1) to assure the exclusions are not applicable and that the property shall be considered for coal exchange.

Some of the commenters' confusion concerning the findings in proposed § 785.19(e) were related to the order of proposed Paragraphs (e)(1) and (e)(2). In the final rule, these paragraphs have been reversed and renumbered accordingly. If the statutory exclusions of § 785.19(b)(2) do not apply then the findings of § 785.19(e)(2) (i) and (ii) will have to be made in order for the operator to mine on the alluvial valley floor. (The finding of § 785.19(e)(2)(iii) does not relate to the exclusions in Section 510(b)(5) of the Act and is always required prior to the issuance of a permit for mining on an AVF.) By denying a permit based on the inability to make the findings in § 785.19(e), the regulatory authority will, in fact, be certifying that the impacts addressed by Section 510(b)(5) (A) or (B) of the Act would occur. This could make the area available for consideration for the coal exchange program.

Based on additional analysis of proposed § 785.19(c), OSM has determined that an additional paragraph was needed to enable the regulatory authority to prohibit surface coal mining and reclamation operations in all or parts of the area to be affected by mining. This addition will enable the regulatory authority, at the request of the applicant, to apply the summary denial provisions to all or parts of the area to be affected by mining.

Section 785.19(d) Application contents: The previous rules in § 785.19(d)(1) provided that once land within the proposed permit area or adjacent area was identified as an alluvial valley floor and the proposed mining operation could have affected an alluvial valley floor or waters that supply alluvial valley floors, the applicant had to submit a complete application for the proposed mining and reclamation operations. The complete application had to include detailed surveys and baseline data required by the regulatory authority for a determination of—

(i) The characteristics of the alluvial valley floor which are necessary to preserve the essential hydrologic functions during the after mining;

(ii) The significance of the area to be affected to agricultural activities;

(iii) Whether the operation will cause, or presents an unacceptable risk of causing, material damage to the quantity or quality of surface of ground waters that supply the alluvial valley floor;

(iv) The effectiveness of proposed reclamation with respect to requirements of the Act and the regulatory program; and

(v) Specific environmental monitoring required to measure compliance with Part 822 during and after mining and reclamation operations.

Previous § 785.19(d) (2) and (3) described in detail the information and surveys required to be submitted as part of the application in addition to the information required for the identification of the AVF's.

This final rule generally retains the above-described requirements of previous § 785.19(d)(1), with a few variations in language to parallel the Act. Previous §§ 785.19(d) (2) and (3) have been removed.

If the regulatory authority has already determined that any of the statutory exclusions in final § 785.19(b)(2) apply, then the applicant will not have to submit information in the permit application, as required by § 785.19(d)(2) (ii) and (iii), as to whether the proposed operation would interrupt, discontinue, or preclude farming on the AVF or whether it would materially damage the quantity or quality of the surface or ground water supplied to the AVF. However, regardless of whether the statutory exclusions were to apply, the applicant must provide data, as required by § 785.19(d)(2)(i), to show that the essential hydrologic functions of the AVF will be preserved throughout the mining and reclamation process.

Final § 785.19(d) will not enumerate the technical data, information, and analysis required for a complete permit application contained in previous § 785.19(d) (2) and (3), but will continue to require generally that sufficient information be submitted to enable the regulatory authority to make the necessary determinations. Because the determinations will have to be supported, the final rules should not change the level of protection afforded AVF's. The principal difference is that the regulatory authority will have the flexibility to adjust the type of data and level of analysis necessary on which to base its determinations.

Two commenters asserted that no documentation is needed with regard to the essential hydrologic functions of an alluvial valley floor (per § 785.19(d)(2)(i)) if the exclusions of Section 510(b)(5)(A) of the Act apply (*i.e.*, if the alluvial valley floor is undeveloped rangeland not significant to farming). One of the commenters went on to reference a footnote in the district court's decision of February 26, 1980 (footnote No. 28, page 53). The other commenter simply asserted that where the statutory exclusions of Section 510(b)(5)(A) of the Act apply, the operation should be exempt from the requirements of Section 515(b)(10)(F) of the Act.

OSM has evaluated the commenters' assertions regarding the footnote in the district court's decision. OSM concludes that regardless of the applicability of the statutory exclusions of Section 510(b)(5) of the Act, the performance standard of Section 510(b)(10)(F) of the Act applies with respect to alluvial valley floors. The wording of Section 510(b)(10)(F) itself requires preservation of the essential hydrologic functions of alluvial valley floors throughout the mining and reclamation process, with no mention of whether the alluvial valley floor meets the statutory exclusions of Section 510(b)(5) of the Act. This concept is supported by a statement in the district court's decision on page 50 that "If the permit area encompasses an alluvial valley floor, the hydrologic protections of Sections 510(b)(3) and 515(b)(10)(F) apply *regardless of whether farming occurs.*" (Emphasis added.) The footnote related only to the validity of OSM's previous rule implementing Section 510(b)(5)(B) of the Act. As discussed elsewhere in this preamble, OSM agrees with the district court's decision that Section 510(b)(5) clearly legislates an exemption to the hydrology protection requirements of Section 510(b)(5)(B) of the Act for operations which will have a negligible impact on the farm's production or where the alluvial valley floor is undeveloped rangeland not significant to farming. However, it is not correct that this is also an exemption from the more general hydrologic protection provisions of Sections 510(b)(3) and 515(b)(10)(F) of the Act.

One commenter requested that in order to provide clarity, the rules should make specific reference to the permit and denial provisions of the Act. More specifically, the commenter suggested that Section 510 of the Act be referenced in § 785.19(d)(2) (ii) and (iii) which implement this section of the Act in terms of supplying such information in permit applications.

OSM has evaluated the commenter's concerns and concludes that the rules appropriately implement the provisions of Section 510(b)(5) (A) and (B) of the Act with respect to alluvial valley floor

protection and that specific reference to Section 510 of the Act is unnecessary.

One commenter expressed concern with the change in terminology of § 785.19(d)(2)(i) from "during and after mining" to "throughout the mining and reclamation process." The commenter went on to assert that this change will not provide the same protection as the previous rule due to long-term ground water quality changes due to mining.

OSM made this change in terminology to more closely reflect the language of the statute. More specifically, Section 515(b)(10)(F) of the Act calls for "preserving *throughout the mining and reclamation process* the essential hydrologic functions of alluvial valley floors in the arid and semiarid areas of the country * * * " (Emphasis added.) The previous phrase "during and after mining" was ambiguous in being open-ended and not providing closure regarding an operator's responsibility. Under the new rule, the operator's responsibility and a regulatory authority's permit evaluation must proceed through the reclamation process until bond release.

Two commenters contended that in cases where the essential hydrologic functions of alluvial valley floors must be restored, the restoration plan should focus on duplicating the pre-mining agricultural productivity as opposed to duplicating the exact pre-mining hydrologic details. One of these commenters pointed out that achieving the latter may be counterproductive in achieving the former. It was suggested that restoration of a topography conducive to flood irrigation ought to be permissible where subirrigation existed previously, provided that agricultural productivity is restored. The commenter went on to assert that the rules should not contain the implication that an identical hydrologic regime must be reconstructed to preserve the essential hydrologic functions.

OSM has evaluated the comments noted above with respect to the suggestion to require restoration of "modified" essential hydrologic functions which maintain the agricultural utility of the alluvial valley floor. The principal objective of Section 515(b)(10)(F) of the Act is to preserve (or restore) the essential hydrologic functions of alluvial valley floors throughout the mining and reclamation process. This statutory provision is implemented in § 822.11 of the alluvial valley floor rules. Permit applications must demonstrate that the essential hydrologic functions of an alluvial valley floor will be preserved outside the permit area and restored within the permit area. The four major components of the essential hydrologic functions of alluvial valley floors include the collection, storage, and regulation of the flow of water and making this water available for agricultural purposes. (See H.R. Rept. No. 95–218, 95th Congress 1st Session at 111–112, 116–118 (1977).)

With respect to the reestablishment of essential hydrologic functions on alluvial valley floors, the components of the essential hydrologic functions (or characteristics which support the components) of an alluvial valley floor do not have to be restored to be identical to their premining state. For example, in a situation where flood irrigation is the essential hydrologic function, a restored ditch system does not have to be replaced in exactly the same location, or with respect to a subirrigated alluvial valley floor, a restored shallow ground water system does not have to be comprised of the same geologic materials or strata. Stated in a different way, particular characteristics of the alluvial valley floor which are necessary to preserve the essential hydrologic function may be modified in the restoration effort so long as they are functionally equivalent to the premining feature.

However, OSM finds no statutory basis for the recommendation of the commenters that the substitution of flood irrigation for subirrigation on affected alluvial valley floors should be permissible. The language of Section 515(b)(10)(F) of the Act is quite clear in that the essential hydrologic functions of alluvial valley floors must be preserved. Although flood irrigation may achieve the same agricultural productivity as subirrigation under a given hydrologic regime, it is generally understood that, in most cases, subirrigation (where it occurs) represents a more reliable water souce and is less costly (from an operational and equipment standpoint) than flood irrigation.Therefore, in addition to achieving similar agricultural productivity, there are other important considerations in the replacement of subirrigation with flood irrigation on alluvial valley floors. Thus, OSM has elected not to modify the subject rule.

One commenter noted that the first sentence of proposed § 785.19(d)(1) was redundant in that both the terms "potentially impacted area" and "mining operation may affect" would have been used in the same sentence. The commenter also pointed out that land would not be included within the potentially impacted area unless it might be affected. The commenter recommended that the following language be substituted: "If land within the potentially impacted area is identified as an alluvial valley floor, the applicant shall submit a complete permit application * * *."

OSM has considered the commenter's concerns and agrees that the proposed use of the term "potentially impacted area" and "mining operation may affect" was confusing. As noted earlier in this preamble, OSM has made several modifications to references to various "areas" throughout the alluvial valley floor protection rules. Therefore, with respect to § 785.19(d)(1), OSM has reinstituted language from the previous section which called for the submission of an application if land within the "premit area or adjacent area" is identified as an alluvial valley floor. Substitution of this language should clarify the areas of consideration for application contents for operations that may affect AVF's or waters supplied to AVF's.

One commenter expressed concern with respect to the clause in proposed § 785.19(d)(1), which states that if an exclusion of Paragraph (b) of § 785.19 applies, then the applicant need not submit the information required in Paragraph (d)(2)(iii) which relates to material damage to the quantity or quality or surface and ground water supplied to an alluvial valley floor. The commenter contended that based on this clause, the applicant will be exempt from supplying pertinent information and reclamation plans to avoid material damage.

This commenter went on to assert that the rules, as specified in § 785.19(d)(1) will allow degradation or diminishment of water supplying an alluvial valley floor.

OSM has evaluated the commenter's concerns noted above. The sentence in § 785.19(d)(1) referenced by the commenter has been inserted to reflect the district court's decision which specified that Section 510(b)(5)(B) of the Act only applies to alluvial valley floors where the statutory exclusions of Section 510(b)(5)(A) of the Act do not apply. In other words, the requirement not to materially damage water supplying an alluvial valley floor only applies where the alluvial valley floor is significant to farming. However, it should be emphasized that regardless of the applicability of Section 510(b)(5)(B) of the Act, the hydrologic protection provisions of Sections 515(b)(10)(F) and 510 (b)(3) of the Act apply, together with their implementing regulations. Therefore, OSM rejects the commenter's concerns and finds that the requirements of § 785.19(d) appropriately implement the statutory provisions relating to hydrologic protection of alluvial valley floors.

One commenter noted concern with respect to modification of § 785.19(d)(2)(ii) to substitute "absolute" test language for the "significance" test of the previous rule. The commenter went on to assert that because Section 510(b)(5) of the Act mentions significance, this modification of the rule would violate the Act.

OSM has evaluated the commenter's concerns and has concluded that the proposed § 785.19(d)(2)(ii) better implements Section 510(b)(5)(A) of the Act than did the previous provision. The final rule states that the complete application shall include detailed surveys and baseline data for a determination by the regulatory authority of whether the operation will avoid during mining and reclamation the interruption, discontinuance, or preclusion of farming on the alluvial valley floor. This provision focuses the determination on the requirements of Section 510(b)(5)(A) of the Act and is more encompassing than the previous requirement to "determine the significance of the area to be affected to agricultural activities." Therefore, OSM does not concur with the commenter's opinion that this change would violate the Act.

One commenter contended that the deletion of the requirement for a determination of whether the operation "presents an unreasonable risk of causing" damage to water systems from previous § 785.19(d)(2)(iii) will restrict the regulatory authority in making critical borderline decisions on the type and amount of protection afforded alluvial valley floors.

OSM has evaluated the commenter's expresed concern and concludes that the final rule, which is the same as the proposed rule, more closely parallels the statute than the previous rule and thus provides the required protection for alluvial valley floors. More specifically, final § 785.19(d)(2) requires the submission of data so that the regulatory authority may make a determination of whether the operation *will* cause material damage to the guantity and quality of surface or ground waters that supply the alluvial valley floor (*i.e.*, an alluvial valley floor to which the exclusions of § 785.19(b) do not apply). This language directly parallels the language of Section 510(b)(5)(B) of the Act. If the regulatory authority concludes that there is an unreasonable risk of causing material damage based on information submitted in accordance with § 785.19(d), then the regulatory authority is required to make a negative finding under § 785.19(e)(2)(ii) of the final rule.

Section 785.19(e) Findings: Previous § 785.19(e) was a confusing section that set forth the findings that have to be made by the regulatory authority to allow mining on or adjacent to an AVF, the applicability of the statutory exclusions of Section 510(b)(5) of the Act, and the criteria for determining whether the facts would support particular statutory exclusions.

Final § 785.19(e) substantially shorter than previous § 785.19(e). As described above, the applicability of the statutory exclusions is covered by final § 785.19(b) and need not be contained in final § 785.19(e).

Final § 785.19(e) will not change the basic requirements for permit approval for mining on or near an AVF and these requirements are presented in a straightforward and simplified manner that closely parallels the Act. The regulatory authority must find that the proposed operations will not interrupt, discontinue, or preclude farming on an AVF and that the quantity and quality of surface and underground waters supplying the AVF will not be materially damaged. These two findings do not have to be made if any of the statutory exclusions apply. However, regardless of whether the statutory exclusions apply, the regulatory authority must find that the proposed operation will comply with Part 822, including preservation of the AVF's essential hydrologic functions (to be discussed in the next section of this preamble) and the other requirements of the regulatory program.

Upon review of proposed § 785.19(e), OSM has reversed proposed Paragraphs (e)(1) and (e)(2). This organizational change will clarify, at the beginning of the paragraph, the findings necessary if the statutory exclusions of § 785.19(b)(2) are applicable.

One commenter was concerned with the deletion in the proposed rules of the criteria for material damage from previous § 785.19(e)(3). The commenter went on to state that the criteria of the previous rules were well documented and widely accepted. This commenter also maintained that without such criteria in the rules and with no reference to a guideline, consistency will be impossible, environmental protection will be compromised, and the efforts of the regulatory authorities will be diluted.

OSM takes exception to the commenter's statement that criteria for material damage are well documented and widely accepted. Such criteria must vary widely, given site-specific conditions relating to alluvial valley floor characteristics such as water quality, vegetation, and general water use. Such criteria are better addressed in guidelines rather than in these rules in order to allow the proper consideration of site-specific conditions. OSM's Alluvial Valley Floor Identification and Study Guidelines address the issue of material damage in considerable detail. In addition, the guidelines (when used in association with the regulatory requirements) will provide necessary guidance to operators and regulatory authorities with respect to material damage to maintain consistency and assure that the environmental protection of alluvial valley floors is not compromised.

One commenter expressed concern with respect to the proposed deletion of previous § 785.19(e)(1)(iv) which required that any change in the land use of lands covered by the proposed mine plan area from its pre-mining use in or adjacent to the alluvial valley floor will not interfere with or preclude the reestablishment of the essential hydrologic functions of the alluvial valley floor. The commenter asserted that the proposed deletion would allow changes in runoff and ground water characteristics of alluvial valley floors, and therefore, the rule change would not support the special protection afforded alluvial valley floors.

OSM has evaluated this comment and concludes that the protection provided by the previous rule is afforded by other sections of these final rules. More specifically, final § 785.19(e)(1)(iii) requires that a finding be made by the regulatory authority that the proposed operations will comply with Part 822 (which includes the requirement to preserve the essential hydrologic functions of alluvial valley floors throughout the mining and reclamation process) and also with other applicable requirements of the Act and the regulatory program. Sections 816.133 and 817.133, which establish the criteria for allowing alternative postmining land uses, do not supersede § 822.11. Therefore, the deletion of previous § 785.19(e)(1)(iv) is inconsequential in terms of the protection afforded alluvial valley floors.

D. Part 822—Performance Standards for Alluvial Valley Floors

Section 822.1 Scope: Final § 822.1 explains that Part 822 contains performance standards for surface coal mining and reclamation operations on or which affect AVF's in the arid and semiarid regions of the country. This section received no comments and is adopted as proposed. Previous § 822.2, which contained the objectives of the

part, is removed to eliminate unnecessary repetitive language.

Section 822.10 Information collection: As proposed, the final rule adds a new § 822.10 on information collection. It will be a codification of the note previously at the beginning of the part that reflects approval by the Office of Management and Budget of the information collection requirements of Part 822. No comments were received on this section.

Section 822.11 Essential hydrologic functions: Previous § 822.11 implemented the performance standard of Section 515(b)(10)(F) of the Act that the essential hydrologic functions of AVF's be preserved throughout the mining and reclamation process. It had three paragraphs. Paragraph (a) of previous § 822.11 established the statutory standard of preserving essential hydrologic functions for AVF's not in the affected area. Paragraph (b) of the previous section, recognizing that mining operations would cause disturbances, required surface coal mining and reclamation operations to reestablish the essential hydrologic functions for AVF's within the affected area. Previous § 822.11 (a) and (b) also required the maintenance or reestablishment of the geologic, hydrologic, and biologic characteristics that support the essential hydrologic functions. Previous § 822.11(c) provided an explanation of the supporting geologic, hydrologic, and biologic characteristics.

OSM has made several changes to previous § 822.11 to make it shorter and to make it more understandable. Paragraphs (a) and (b) in final § 822.11 are similar to their previous counterparts. In these paragraphs, reference to the statutory language of minimizing disturbance to the hydrologic balance will be included in order to clarify the statutory context of Section 515(b)(10) of the Act in which this requirement was developed by Congress. Reference to the particular characteristics to be maintained or reconstructed is eliminated because the essential hydrologic function of the alluvial valley floor can be protected without preserving or reestablishing the exact geologic, hydrologic, and biologic conditions. The environmental conditions of an AVF, including geologic, hydrologic and biologic characteristics, vary widely with site-specific conditions and may be modified so long as the essential hydrologic function retains or is restored to its premining functional equivalent.

Further, maintenance or reconstruction of the geologic or biologic characteristics would not necessarily ensure that the essential hydrologic functions are preserved. Previous §§ 822.11(c) and 785.19(d)(3), which identified these characteristics, are removed entirely. Such characteristics are addressed, however, in OSM's AVF guidelines.

The previous rules often confused protection of the hydrologic functions of alluvial valley floors with the physical characteristics of those valley floors. While in some cases the physical characteristics must be recreated to reestablish a certain function, such as water storage, in other situations the function of the alluvial valley floor may be preserved by an alluvial valley floor with slightly different physical characteristics. The final rules recognize this difference.

Two commenters expressed concern as to the deletion of previous § 822.11(c), which provided a cross-reference to § 785.19(d)(3). The latter section included information about the hydrologic, geologic, and biologic characteristics that support the essential hydrologic functions of alluvial valley floors. Both Commenters maintained that this cross-reference would provide valuable information to individuals in the future.

OSM finds that the deletion of Paragraph (c) of previous § 822.11 does not weaken the protection for AVF's because the requirement to identify the characteristics that support the essential hydrologic functions of alluvial valley floors is included in § 785.19(d)(2)(i). A cross-reference in Part 822 is superfluous. The definition for the term "essential hydrologic functions" in 30 CFR 701.5 will lead to an identification of the characteristics that must be considered in particular situations.

One commenter also remarked upon the proposed substitution of the phrase "outside the minesite" for the phrase "not within an affected area" in § 822.11(a). The commenter contended that this substitution moves the area of preservation inward toward the mine to some degree; however, the commenter also stated that this is a minimal change. One commenter asserted his full support for the proposed changes to this section of the rules.

OSM proposed to substitute the term "outside the minesite" for "not within the affected area" in § 822.11(a) to track the phrase used in Section 515(b)(10) of the Act. The final rule does not adopt this change. Instead it uses the phrase "not within the permit area" in § 822.11(a) and the phrase "within the permit area" in § 822.11(b). These changes have been made to reflect the recent revisions to the terms "permit area" and "affected area" (48 FR 14814, April 5, 1983) and to track the intent of the language of Section 515(b)(10) of the Act, using terms that are defined in the rules.

The phrase "in associated offsite areas" has also been deleted as discussed earlier under *General Comments.*

Previous and final § 822.11 apply to all alluvial valley floors, irrespective of the area's significance to farming. The concern of Congress for alluvial valley floors that would be mined or affected by adjacent mining was that long term permanent damage not be caused to the AVF's hydrologic system. Recognizing that total prevention of hydrologic effects from mining was impossible, Congress required minimization of the effects (including those on the hydrologic function of alluvial valley floors) to assure the impacts "are not irreparable" (H. Rept. No. 95-218, cited previously, p. 110). Thus, the purpose of § 822.11 is the longer term protection of essential hydrologic functions while the shorter term effects on agricultural activities on alluvial valley floors is protected by the "materially damage" requirements of Section 510(b)(5) of the Act implemented by § 822.12 of the rules.

Section 822.12 Protection of agricultural activities: Previous § 822.12 implemented the requirements of Section 510(b)(5) of the Act that surface coal mining operations should not interrupt, discontinue, or preclude farming and should not materially damage the quantity and quality of surface or underground waters supplying AVF's. However, in previous § 822.12 the undeveloped rangeland and small acreage statutory exclusions were applied in a manner inconsistent with the February 26, 1980, district court decision, described earlier in this preamble.

The statutory exclusions in the provisos of Sections 510(b)(5) and 506(d)(2) of the Act were also implemented imprecisely in previous § 822.12(d). Previous § 822.12(d) incorrectly limited the applicability of the Section 510(b)(5) proviso to lands which were identified in a reclamation plan approved by the State prior to August 3, 1977. This language was inserted in the March 13, 1979, rules (44 FR 15284) in an unsuccessful attempt to implement the proviso of Section 506(d)(2) of the Act.

In addition to implementing the requirements and exclusions of Section 510(b)(5) of the Act, previous § 822.12 (b) and (c) also required that when environmental monitoring shows that operations are violating the requirements of § 822.12, the operations

must cease and remedial actions that are approved by the regulatory authority must be taken.

As proposed, the title of § 822.12 has been changed to "Protection of agricultural activities" to clarify the purpose of the section. The section has been reorganized to implement the February 26, 1980, district court decision Final § 822.12(a) sets forth the prohibitions of Section 510(b)(5) of the Act. The exclusions relating to agricultural activities are included in final § 822.12(b) (1) and (2) and final § 822.12(b) (3) and (4) correctly implement the statutory exclusions established by the provisos of Sections 506(b)(2) and 510(b)(5) of the Act.

Final § 822.12 has been reorganized from the proposed rule for clarity. To assist the reader in understanding the redesignations the following derivation table shows the relationship of final § 822.12 to the proposed § 822.12.

DERIVATION TABLE—SECTION 822.12

Final rule	Proposed rule
(a) Intro	(a) Intro and (b) Intro.
(a)(1)	(a).
(a)(2)	(b).
(b)	(b) and (c).
(b)(1)	(a)(1).
(b)(2)	(a)(2).
(b)(3)	(c)(1).
(b)(3)(i)	(c)(1)(i).
(b)(3)(ii)	(c)(1)(ii).
(b)(4)	(c)(2).
(b)(4)(i)	(c)(2)(i).
(b)(4)(ii)	(c)(2)(ii).

The requirement to cease mining and to take remedial action contained in previous § 822.12 (b) and (c) is deleted. Contrary to the statement in the March 13, 1979, **Federal Register** preamble adopting the previous requirements (44 FR 15283), such requirements are not necessary to make clear the duty of the regulatory authority and the permittee.

These responsibilities are adequately stated in existing 30 CFR 786.29 which requires a permittee to take all possible steps to minimize any adverse impact on the environment resulting from any term or condition of the permit. Such steps include the immediate implementation of measures necessary to comply. If the only means for the permittee to comply with the terms or conditions of the permit is to cease mining, the permittee must cease mining under § 786.29. The requirements of § 786.29 have been proposed for retention in 30 CFR 773.17(e) as set forth in OSM's "Final Environmental Impact Statement OSM EIS–1: Supplement," Volume III, p. 53.

One commenter stated that the preamble assurances that Sections 510(b)(5) and 515(b)(10)(F) of the Act require protection of agricultural uses is ludicrous because OSM consciously decided not to implement that protection by explicit rulemaking.

OSM has considered this comment and concludes that § 822.12 of the proposed rules correctly implements the agricultural protection provisions included in the Act with respect to alluvial valley floors. Therefore, OSM rejects this comment.

Section 822.12(a)(2) has been modified from the proposal to delete "agricultural activities" and substitute the term "farming." This change in the rules provides greater consistency with Section 510(b)(5)(A) of the Act. (Further discussion of this change is provided in the preamble to § 785.19(b)(3) which discusses the definition of the term "farm" and the relationship of the terms "farming" and "agricultural activities.")

Two commenters expressed concern about the deletion of previous § 822.12 (b) and (c) which called for the cessation of mining operations until remedial measures are taken if environmental monitoring shows that a surface coal mining operation is interrupting, discontinuing, or precluding farming on alluvial valley floors or is materially damaging the quantity or quality of water that supplies alluvial valley floors, respectively. One of the commenters asserted that these paragraphs should be retained so that the option remains to cease mining. This commenter also maintained that without these paragraphs, OSM's ability to regulate would be limited. The other commenter noted that the proposed changes would allow mining to proceed, leaving mitigation of the conditions to the regulatory authority, which violates the Act. One other commenter stated that § 786.29, which was referenced in the preamble to the proposed rules, does not adequately protect alluvial valley floors from damage. He asserted that this section deals with public health and safety and does not explicitly require a cessation order until approved remedial measures are taken by the operator. This commenter also asserted that the proposed rule substantially weakens enforcement.

OSM disagrees with the commenters. Section 786.29(a) provides a degree of protection and enforcement capability comparable to the deletion section. More specifically, §786.29 requires that "The permittee shall take all possible steps to minimize any adverse impact to the *environment* or public health and safety resulting from noncompliance with any term or condition of the permit * * *." (Emphasis added.) Section 786.29 is applicable to environmental impacts in addition to health and safety concerns. Possible steps to minimize adverse impacts may include cessation of mining operations with respect to alluvial valley floors. Therefore, the deletion of these paragraphs of previous § 822.12, considering the protection afforded by § 786.29, does not represent a weaking of enforcement or a violation of the Act. Therefore, OSM rejects the comments noted above with respect to this matter.

OSM has characterized the "small acreage statutory exclusion" in final § 822.12(b)(2) to include situations "where farming on the alluvial valley floor that would be affected by the surface coal mining operation is of such small acreage as to be of negligible impact on the farm's agricultural production." These changes from proposed § 822.12(a)(2) will provide consistency with the Act and will minimize any confusion with respect to the exclusions of Section 510(b)(5).

One commenter expresses concern that proposed § 822.12(c)(1)(ii), which implemented the "grandfather" proviso of Section 510(b)(5) of the Act, says only "regulatory authority" while the statute in Section 510(b)(5) of the Act uses the term "State regulatory authority." The commenter asserted that this improperly lumps Federal regulatory authorities with the States. The commenter urges that the original intent of honoring only State approvals should be continued.

In response to this comment, OSM has modified the language of final § 822.12(b)(3)(ii) to refer to approval of the "State regulatory authority" in order to provide consistency with the proviso of Section 510(b)(5) of the Act and to minimize any confusion with regard to the source of the approval necessary to take advantage of the proviso. It should be noted that in the year preceding the passage of the Act, there was no "State regulatory authority" or "regulatory authority" as those terms are defined in the Act, and therefore the term is used in this context to refer to the State agency with responsibilities for surface coal mining operations prior to passage of the Act.

Final § 822.12(b)(4), which was proposed as § 822.12(c)(2), implements Section 506(d)(2) of the Act which states that if surface coal mining operations authorized by a permit issued pursuant to the Act were not subject to the standards contained in Sections 510(b)(5) (A) and (B) of the Act by reason of complying with the proviso of Section 510(b)(5), then the portion of the application for renewal of the permit which addresses any new areas previously identified in the reclamation plan submitted pursuant to Section 508 of the Act shall not be subject to the standards of Sections 510(b)(5) (A) and

(B). A commenter asserted that the addition of proposed § 822.12(c)(2) to the rules improperly extends the statutory exclusion of Section 510 of the Act for a renewal or an extension of an existing permit. The commenter then went on to state that an operation that was an expansion of another must have approved alluvial valley floor compliance responsibilities.

OSM has carefully reviewed the language of final § 822.12(b)(4) and finds that it is consistent with the language and intent of Section 506(d)(2) of the Act. It should be emphasized that for an existing operation to take advantage of the exclusion provided by this portion of the statute and rules the land must have been previously identified in a reclamation plan submitted under Part 780 or Part 784 *and* the original permit area of the operation was excluded from the protections of Section 510(b)(5) (A) and (B) of the Act by virtue of the proviso of Section 510(b)(5) of the Act. Since the proposed rule is consistent with the Act, it is not necessary to modify the rule.

Section 822.13 Monitoring: Previous § 822.13, entitled "Protection of agricultural uses," required the reestablishment of agricultural utility and levels of productivity of AVF's in affected areas. OSM has deleted § 822.13 because it was unnecessary. The postmining land use provisions in §§ 816.133 and 817.133 already necessitate the restoration of the land to the same capability as existed before mining. Also, the revegetation rules in §§ 816.111 through 816.116 and §§ 817.111 through 817.116 and, to the extent applicable, the prime farmland rules of 30 CFR Part 823 require the reestablishment of premining vegetation. Finally, the requirements of Sections 510(b)(5) and 515(b)(10)(F) of the Act assures the protection of agricultural uses.

Previous § 822.14 is revised and redesignated as § 822.13 and the basic monitoring scheme is retained. Previous § 822.14 required the establishment and maintenance of an environemental monitoring system on AVF's during surface coal mining and reclamation operations and continuation until all bonds are released. OSM has made changes to clarify that the requirements for monitoring on AVF's should parallel the requirements of Sections 510(b)(5) and 515(b)(10)(F) of the Act and the performance standards in §§822.11 and 822.12.

A number of concerns were raised by commenters with respect to changes in the monitoring requirements for alluvial valley floors proposed in § 822.13. One commenter noted that the proposed changes shift the emphasis from protection of characteristics supporting the essential hydrologic functions to compliance with § 822.11 and from protection of agricultural utility to compliance with § 822.12. The commenter went on to note that since all specific references to essential hydrologic functions and agricultural utility have been excised from the requirements of Part 822 no specific direction is available with respect to these terms. The same commenter also took issue with the proposed deletion of previous § 822.14(c) which called for monitoring to identify previously unidentified characteristics of alluvial valley floors and to evaluate the importance of these characteristics. In addition, one commenter noted that certain terminology in the alluvial valley floor monitoring requirements (namely, "at adequate frequencies" and "routinely be made available to the regulatory authority") can be interpreted and enforced by the regulatory authority in an arbitrary manner. Therefore, the commenter requested that OSM provide guidance in the rules concerning such monitoring activities. The commenter went on to recommend that because it is "long-term trends" that the data are to indicate, quarterly monitoring with annual reporting is reasonable. One commenter also recommended deletion of the term "agricultural activities" in § 822.13(a)(2) and substitution of the term "farming" to provide consistency with Section 510(b)(5)(A) of the Act.

OSM has reviewed the comments received with respect to alluvial valley floor monitoring. In response to these specific comments, OSM finds that requiring monitoring of the essential hydrologic functions (as protected under § 822.11) and of agricultural activities (as protected under § 822.12) results in no lesser protection than the previous rules. Information with respect to the characteristics supporting the essential hydrologic functions and the agricultural utility of the alluvial valley floor will be included in permit applications. The applicable performance standards of Part 822 and the monitoring system will be based on conditions described in the permit application. Thus, monitoring of essential hydrologic functions and agricultural activities in accordance with §§ 822.11 and 822.12, respectively, will provide an equal degree of protection,. This commenter's concern wih respect to the deletion of specific information requirements for essential hydrologic functions and agricultural utility is addressed elsewhere in this preamble.

With respect to the deletion of previous § 822.14(c) which called for monitoring to identify previously unidentified characteristics and to evaluate the importance of all characteristics, the final alluvial valley floor monitoring rules provide the necessary monitoring to assure conformance with the alluvial valley floor protection provisions of Sections 510 and 515 of the Act and the performance standards of Part 822 of the rules. In addition, general hydrologic monitoring required under the hydrologic protection sections of 30 CFR Parts 816 and 817 will provide an additional monitoring program for lands which may be affected by mining operations. Finally, it should be pointed out that if the regulatory authority believes that additional monitoring is necessary to further identify, define, or understand characteristics of designated alluvial valley floors, the regulatory authority may require this additional monitoring under § 822.13.

OSM has evaluated the commenter's concern that general reference to monitoring frequencies and routine submission of data may be interpreted and enforced by the regulatory authority in an arbitrary manner. OSM has also reviewed the commenter's recommendation for monitoring and reporting frequencies. The frequencies for field monitoring and data reporting with respect to alluvial valley floors should be handled on a case-by-case basis to reflect site-specific conditions. Although the commenter's specific recommendations for quarterly monitoring with annual reporting may be appropriate in some cases, site-specific conditions may dictate other frequencies. The alluvial valley floor monitoring rules, as proposed, provide this necessary flexibility. The possibility of arbitrary enforcement of monitoring requirements will not be increased by these rules. The key factor, under either the previous or new rules, is the ability and intent of the regulatory authority to enforce the regulatory program. OSM oversight will assist in ensuring proper implementation of the AVF monitoring requirement, as well as the remainder of the regulatory program.

Two commenters objected to OSM's proposed elimination of § 822.13 of the previous rules. They questioned whether the provisions of Section 515(b)(2) of the Act would be met and pointed out that without previous § 822.13, the areas would be treated like ordinary lands. One of the commenters believed OSM's reason for eliminating the section was not valid because it is based on other sections of the regulatory program that are also revised and weakened.

As explained earlier, provisions contained in other sections of the permanent program rules require reestablishment of the premining capability to sustain vegetation and levels of agricultural productivity of alluvial valley floors in affected areas.

Reference Materials

The reference materials used to develop these final rules are the same as those listed in the previous rules (44 FR 14924 and 15087–15094), including the material listed below.

Schmidt, J., 1980, Alluvial Valley Floor Identification and Study Guidelines.

III. Procedural Matters

National Environmental Policy Act

OSM has analyzed the impacts of these final rules in the "Final Environmental Impact Statement OSM EIS–1: Supplement" (FEIS) according to Section 102(2)(c) of the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4332(2)(c)). This FEIS is available in OSM's Administrative Record in Room 5315, 1100 L Street, NW., Washington, D.C., or by mail request to Mark Boster, Chief, Branch of Environmental Analysis, Room 134, Interior South Building, U.S. Department of the Interior, Washington, D.C. 20240. This preamble serves as the record of decision under NEPA. Although there has been a number of editorial changes and clarifications, these final rules were analyzed as the preferred alternative A in the FEIS.

Executive Order 12291

The Department of the Interior has determined that this document is not a major rule and does not require a regulatory impact analysis under Executive Order 12291.

Regulatory Flexibility Act

These rules have also been examined pursuant to the Regulatory Flexibility Act, 5 U.S.C. 601 *et seq.*, and OSM has certified that these rules do not have significant economic impact on a substantial number of small entities. The rule is expected to ease the regulatory burden on small coal operators by giving the State regulatory authorities the discretion of reducing the amount of information that will have to accompany each permit application.

Federal Paperwork Reduction Act

The information collection requirements in 30 CFR 785.19 and 822.13 were approved by the Office of Management and Budget (OMB) under 44 U.S.C. 3507 and assigned clearance numbers 1029–0040 and 1029–0049, respectively. The information required by §§ 785.19 and 822.13 is being collected to meet the requirements of Sections 510(b)(5) and 515(b)(10)(F) of the Act, which protect alluvial valley floors from the adverse effects of surface coal mining operations. The information required by § 785.19 will be used to give the regulatory authority a sufficient baseline upon which to assess the impact of the proposed operation during the permanent regulatory program. The recordkeeping requirements in § 822.13 will measure compliance with performance standards during and after mining operations. The obligation to respond is mandatory.

Agency Approval

Section 516(a) requires that, with regard to rules directed toward the surface effects of underground mining, OSM must obtain written concurrence from the head of the department which administers the Federal Mine Safety and Health Act of 1977, the successor to the Federal Coal Mine Health and Safety Act of 1969. OSM has obtained the written concurrence of the Assistant Secretary for Mine Safety and Health, U.S. Department of Labor.

List of Subjects

30 CFR Part 701

Coal mining, Law enforcement, Surface mining, Underground mining.

30 CFR Part 785

Coal mining, Reporting requirements, Surface mining, Underground mining.

30 CFR Part 822

Coal mining, Environmental protection, Surface mining, and Underground mining.

Accordingly, 30 CFR Parts 701, 785, and 822 are amended as set forth herein.

Dated: June 22, 1983.

J. J. Simmons III,
Under Secretary.

PART 701—PERMANENT REGULATORY PROGRAM

1. Section 701.5 is amended by revising the definitions of "Agricultural activities," "Essential hydrologic functions," "Materially damage the quantity or quality of water," "Subirrigation," and by removing the definition of "Unconsolidated stream laid deposits holding streams" to read as follows:

§ 701.5 Definitions.

* * * * *

Agricultural activities or *farming* means, with respect to alluvial valley floors, the use of any tract of land for the production of animal of vegetable life, based on regional agricultural practices, where the use is enhanced or facilitated by subirrigation or flood irrigation. These uses include, but are not limited to, the pasturing or grazing of livestock, and the cropping, cultivation, or harvesting of plants whose production is aided by the availability of water from subirrigation or flood irrigation. These uses do not include agricultural activities which have no relationship to the availability of water from subirrigation or flood irrigation practices.

* * * * *

Essential hydrologic functions means the role of an alluvial valley floor in collecting, storing, regulating, and making the natural flow of surface or ground water, or both, usefully available for agricultural activities by reason of the valley floor's topographic position, the landscape, and the physical properties of its underlying materials. A combination of these functions provides a water supply during extended periods of low precipitation.

* * * * *

Materially damage the quantity or quality of water means, with respect to alluvial valley floors, to degrade or reduce by surface coal mining and reclamation operations the water quantity or quality supplied to the alluvial valley floor to the extent that resulting changes would significantly decrease the capability of the alluvial valley floor to support agricultural activities.

* * * * *

Subirrigation means, with respect to alluvial valley floors, the supplying of water to plants from underneath or from a semisaturated or saturated subsurface zone where water is available for use by vegetation.

* * * * *

(Pub. L. 95–87, 30 U.S.C. 1201 *et seq.*)

PART 785—REQUIREMENTS FOR PERMITS FOR SPECIAL CATEGORIES OF MINING

2. Section 785.19 is revised to read as follows:

§ 785.19 Surface coal mining and reclamation operations on areas or adjacent to areas including alluvial valley floors in the arid and semiarid areas west of the 100th meridian.

(a) *Alluvial valley floor determination.* (1) Permit applicants who propose to conduct surface coal mining and reclamation operations within a valley holding a stream or in a

location where the permit area or adjacent area includes any stream, in the arid and semiarid regions of the United States, as an initial step in the permit process, may request the regulatory authority to make an alluvial valley floor determination with respect to that valley floor. The applicant shall demonstrate and the regulatory authority shall determine, based on either available data or field studies submitted by the applicant, or a combination of available data and field studies, the presence or absence of an alluvial valley floor. Studies shall include sufficiently detailed geologic, hydrologic, land use, soils, and vegetation data and analysis to demonstrate the probable existence of an alluvial valley floor in the area. The regulatory authority may require additional data collection and analysis or other supporting documents, maps, and illustrations in order to make the determination.

(2) The regulatory authority shall make a written determination as to the extent of any alluvial valley floors within the area. The regulatory authority shall determine that an alluvial valley floor exists if it finds that—

(i) Unconsolidated streamlaid deposits holding streams are present; and

(ii) There is sufficient water available to support agricultural activities as evidenced by—

(A) The existence of current flood irrigation in the area in question;

(B) The capability of an area to be flood irrigated, based on evaluations of typical regional agricultural practices, historical flood irrigation, streamflow, water quality, soils, and topography; or

(C) Subirrigation of the lands in question derived from the ground-water system of the valley floor.

(3) If the regulatory authority determines in writing that an alluvial valley does not exist pursuant to Paragraph (a)(2) of this section, no further consideration of this section is required.

(b) *Applicability of statutory exclusions.* (1) If an alluvial valley floor is identified pursuant to paragraph (a)(2) of this section and the proposed surface coal mining operation may affect this alluvial valley floor or waters that supply the alluvial valley floor, the applicant may request the regulatory authority, as a preliminary step in the permit application process, to separately determine the applicability of the statutory exclusions set forth in paragraph (b)(2) of this section. The regulatory authority may make such a determination based on the available data, may require additional data collection and analysis in order to make the determination, or may require the applicant to submit a complete permit application and not make the determination until after the complete application is evaluated.

(2) An applicant need not submit the information required in paragraphs (d)(2) (ii) and (iii) of this section and a regulatory authority is not required to make the findings of paragraphs (e)(2) (i) and (ii) of this section when the regulatory authority determines that one of the following circumstances, heretofore called statutory exclusions, exist:

(i) The premining land use is undeveloped rangeland which is not significant to farming;

(ii) Any farming on the alluvial valley floor that would be affected by the surface coal mining operation is of such small acreage as to be of negligible impact on the farm's agricultural production. Negligible impact of the proposed operation on farming will be based on the relative importance of the affected vegetation and water of the developed grazed or hayed alluvial valley floor area to the farm's production over the life of the mine; or

(iii) The circumstances set forth in § 822.12(b) (3) or (4) of this chapter exist.

(3) For the purposes of this section, a farm is one or more land units on which agricultural activities are conducted. A farm is generally considered to be the combination of land units with acreage and boundaries in existence prior to August 3, 1977, or, if established after August 3, 1977, with those boundaries based on enhancement of the farm's agricultural productivity and not related to surface coal mining operations.

(c) *Summary denial.* If the regulatory authority determines that the statutory exclusions are not applicable and that any of the required findings of paragraph (e)(2) of this section cannot be made, the regulatory authority may, at the request of the applicant:

(1) Determine that mining is precluded on the proposed permit area and deny the permit without the applicant filing any additional information required by this section; or

(2) Prohibit surface coal mining and reclamation operations in all or parts of the area to be affected by mining.

(d) *Application contents for operations affecting designated alluvial valley floors.* (1) If land within the permit area or adjacent area is identified as an alluvial valley floor and the proposed surface coal mining operation may affect an alluvial valley floor or waters supplied to an alluvial valley floor, the applicant shall submit a complete application for the proposed surface coal mining and reclamation operations to be used by the regulatory authority together with other relevant information as a basis for approval or denial of the permit. If an exclusion of paragraph (b)(2) of this section applies, then the applicant need not submit the information required in paragraphs (d)(2) (ii) and (iii) of this section.

(2) The complete application shall include detailed surveys and baseline data required by the regulatory authority for a determination of—

(i) The characteristics of the alluvial valley floor which are necessary to preserve the essential hydrologic functions throughout the mining and reclamation process;

(ii) Whether the operation will avoid during mining and reclamation the interruption, discontinuance, or preclusion of farming on the alluvial valley floor;

(iii) Whether the operation will cause material damage to the quantity or quality of surface or ground waters supplied to the alluvial valley floor;

(iv) Whether the reclamation plan is in compliance with requirements of the Act, this chapter, and regulatory program; and

(v) Whether the proposed monitoring system will provide sufficient information to measure compliance with Part 822 of this chapter during and after mining and reclamation operations.

(e) *Findings.* (1) The findings of paragraphs (e)(2) (i) and (ii) of this section are not required with regard to alluvial valley floors to which are applicable any of the exclusions of paragraph (b)(2) of this section.

(2) No permit or permit revision application for surface coal mining and reclamation operations on lands located west of the 100th meridian west longitude shall be approved by the regulatory authority unless the application demonstrates and the regulatory authority finds in writing, on the basis of information set forth in the application, that—

(i) The proposed operations will not interrupt, discontinue, or preclude farming on an alluvial valley floor;

(ii) The proposed operations will not materially damage the quantity or quality of water surface and underground water systems that supply alluvial valley floors; and

(iii) The proposed operations will comply with Part 822 of this chapter and the other applicable requirements of the Act and the regulatory program.

(Pub. L. 95-87, 30 U.S.C. 1201 *et seq.*)

3. Part 822 is revised to read as follows:

PART 822—SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS—OPERATIONS IN ALLUVIAL VALLEY FLOORS

Authority: Pub. L. 95–87, 30 U.S.C. 1201 *et seq.*

§ 822.1 Scope.

This part sets forth additional requirements for surface coal mining and reclamation operations on or which affect alluvial valley floors in the arid and semiarid regions of the country.

§ 822.10 Information collection.

The information collection requirements contained in § 822.13 have been approved by the Office of Management and Budget under 44 U.S.C. 3507 and assigned clearance number 1029–0049. The information is being collected to meet the requirements of Sections 510(b)(5) and 515(b)(10)(F) of the Act which provide the information collection requirements and performance standards for alluvial valley floors. This information will be used to enable the regulatory authority to assess the impact of the proposed operation during the permanent regulatory program. The obligation to respond is mandatory.

§ 822.11 Essential hydrologic functions.

(a) The operator of a surface coal mining and reclamation operation shall minimize distrubances to the hydrologic balance by preserving throughout the mining and reclamation process the essential hydrologic functions of an alluvial valley floor not within the permit area.

(b) The operator of a surface coal mining and reclamation operation shall minimize disturbances to the hydrologic balance within the permit area by reestablishing throughout the mining and reclamation process the essential hydrologic functions of alluvial valley floors.

§ 822.12 Protection of agricultural activities.

(a) *Prohibitions.* Surface coal mining and reclamation operations shall not: (1) Interrupt, discontinue, or preclude farming on alluvial valley floors; or (2) cause material damage to the quantity or quality of water in surface or underground water systems that supply alluvial valley floors.

(b) *Statutory exclusions.* The prohibitions of Paragraph (a) of this section shall not apply—

(1) Where the premining land use of an alluvial valley floor is undeveloped rangeland which is not significant to farming;

(2) Where farming on the alluvial valley floor that would be affected by the surface coal mining operation is of such small acreage as to be of negligible impact on the farm's agricultural production;

(3) To any surface coal mining and reclamation operation that, in the year preceding August 3, 1977—

(i) Produced coal in commercial quantities and was located within or adjacent to an alluvial valley floor; or

(ii) Obtained specific permit approval by the State regulatory authority to conduct surface coal mining and reclamation operations within an alluvial valley floor; or

(4) To any land that is the subject of an application for renewal or revision of a permit issued pursuant to the Act which is an extension of the original permit, insofar as: (i) The land was previously identified in a reclamation plan submitted under either Part 780 or 784 of this chapter, and (ii) the original permit area was excluded from the protection of Paragraph (a) of this section for a reason set forth in Paragraph (b)(3) of this section.

§ 822.13 Monitoring.

(a) A monitoring system shall be installed, maintained, and operated by the permittee on all alluvial valley floors during surface coal mining and reclamation operations and continued until all bonds are released in accordance with Subchapter J of this chapter. The monitoring system shall provide sufficient information to allow the regulatory authority to determine that—

(1) the essential hydrologic functions of alluvial valley floors are being preserved outside the permit area or reestablished within the permit area throughout the mining and reclamation process in accordance with § 822.11;

(2) Farming on lands protected under § 822.12 is not being interrupted, discontinued, or precluded; and

(3) The operation is not causing material damage to the quantity or quality of water in the surface or underground systems that supply alluvial valley floors protected under § 822.12.

(b) Monitoring shall be conducted at adequate frequencies to indicate long-term trends that could affect compliance with §§ 822.11 and 822.12.

(c) All monitoring data collected and analyses thereof shall routinely be made available to the regulatory authority.

[FR Doc. 83–17303 Filed 6–27–83; 8:45 am]
BILLING CODE 4310–05–M